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JAN 13 1922

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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See Illustrated Advertisement Page 100, Jan. 28, 1921.

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See Advertisement page 62. 9091

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See Full Page Advt., page 70, Dec. 9.

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See Advertisement page 60. 3402

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See half-page Advertisement page 73, Dec. 23.

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Tenders for Sale or Hire are due at the above mentioned address by Noon, Tuesday, the 10th January, 1922. S 968

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LITTLETON RESERVOIR.
VENTURI METERS.

The Metropolitan Water Board invite

Tenders for the Supply of the

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Tenders, enclosed in sealed envelopes addressed to "The Clerk of the Board, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, Clerkenwell, E.C. 1," and endorsed "Tender for Venturi Meters, Littleton Reservoir," must be delivered at the Offices of the Board not later than Ten a.m. on Wednesday, 1st February, 1922.
The Board do not bind themselves to accept the lowest or any Tender.

W. MOON,
Clerk of the Board.

Offices of the Board,
New River Head,
173, Rosebery Avenue,
Clerkenwell, E.C. 1.
24th December, 1921. S 983

MUNICIPAL COUNCIL OF JOHANNESBURG.
CONTRACT 997.

Sealed Tenders, Endorsed

"Contract 997," will be received by the Town Clerk, Tender Box, Municipal Offices, Johannesburg, not later than Twelve noon on Friday, 3rd March, 1922, for SUPPLY and ERECTION of COMBINED POWER, HEATING and DRYING PLANT for Abattoirs. Drawings and Documents can be viewed at the Council's London Agents, Messrs. E. W. CARLING & Co., St. Dunstan's Buildings, St. Dunstan's Hill, London, E.C. 3, and copies obtained on deposit of £1 1s.
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S. S. BERT ANDREWS,
Town Engineer. S 987

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The Directors are prepared to receive up to Noon on Friday, 20th January:—

Tenders for the Supply of—

1. LOCOMOTIVE BOILERS.
2. FILES.
3. PICKS, BALLAST RAKES, PHOWRAHS, and SHOVELS.
4. GRINDING WHEELS.

Tenders must be made on forms, copies of which, with specification, can be obtained at these offices on payment of 20s. each for No. 1, and 10s. each for Nos. 2, 3 and 4 (which will not be returned).
The Directors do not bind themselves to accept the lowest or any Tender.

S. G. S. YOUNG,
Secretary.

Offices: The White Mansion,
91, Petty France,
Westminster, S.W. 1.
23rd December, 1921. S 979

PORT OF BRISTOL.
NEW ADMINISTRATIVE OFFICES,
AVONMOUTH DOCKS.

The Docks Committee are prepared to receive

Tenders for the Construction

of NEW ADMINISTRATIVE OFFICES, at the Avonmouth Docks.
On and after Wednesday, the 4th January, 1922, copies of the Specification and Contract drawings can be obtained from the undersigned on production of a receipt showing that a deposit of £3 has been paid to the Bristol Docks Committee, 19, Queen Square, Bristol, to whom all cheques must be made payable. The deposit will be returned to *bona fide* tenderers after the receipt of the tender with all the prescribed documents and drawings.
Tenders must be enclosed in a sealed envelope, endorsed "Tender for Administrative Offices" and addressed to the General Manager and Secretary of the Docks Committee, 19, Queen Square, Bristol, and must be delivered to him accompanied by all the prescribed documents and drawings before Ten a.m. on Wednesday the 25th day of January, 1922.
The Docks Committee do not bind themselves to accept the lowest or any Tender.

THOMAS A. PHAUB,
Engineer.

Engineer's Office,
Avonmouth Docks.
28th December, 1921. S 997

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The Directors are prepared to receive

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		Fee for Specification.
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No. 4.	Bolts, Nuts and Rivets	10/-
No. 5.	Canvases, &c.	10/-
No. 6.	Ropes	7/6
No. 7.	Linoleum	7/6

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.
The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Spare parts of Carriages, Wagons," or as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 17th January, 1922.
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R. H. WALPOLE,
Secretary.

Company's Offices,
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London, 28th December, 1921. S 973

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N. L. FLEMING, Town Clerk.

Town Hall, Bradford.
21st December, 1921. S 970

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12,500 KW. TURBO-GENERATOR FOR THE LIVERPOOL CORPORATION ELECTRICITY WORKS.

We illustrate on the present page, pages 875 and 876, and on Plate XLVI, a highly interesting steam turbine and generator which Mr. H. Dickinson, M.I.E.E., the City Electrical Engineer for Liverpool, has recently installed at the corporation power station. The unit has been designed and constructed by the Metropolitan-Vickers Electrical Company, Limited, of Trafford-park, Manchester, and embodies some very notable departures from the normal type of impulse steam turbine. These innovations we shall describe in due course. The general arrangement of the plant as erected in place is clearly set forth in Figs. 1 and 2, annexed. The turbine is designed to develop under full load conditions 12,500 kw. but can take an overload of 25 per cent. The unit is small for its output and is, we believe, the largest generating set yet designed to run at 3,000 r.p.m. In fact a curve exhibited by Mr. J. P. Johnson at a meeting of the American Institute of Electrical Engineers in the autumn of 1919 indicates a capacity of somewhat under 10,000 kw. as the limit of size consistent with a rotary speed of 3,000 r.p.m. Of course it must be borne in mind in this connection that at Liverpool the vacuum is low, and thus the conditions premised in Mr. Johnson's paper are not strictly comparable with those at Liverpool. The difficulty in constructing high-speed units of large capacity is only in part due to questions of centrifugal stresses, since it is also by no means easy in such cases to keep down the "throwaway" losses arising from the carry-over of kinetic energy to the exhaust. Indeed, in the case of certain high-speed turbines which have been built, although the steam rate is very low, these losses constitute fully 7 per cent. of the total thermodynamic head available at Liverpool.

As is apparent from the general arrangement, Figs. 1 and 2, the turbine at Liverpool is materially smaller than the generator to which it is coupled, its overall dimensions being 17 ft. in length, 13 ft. in width by 6 ft. 9 in. in height, and its weight is 50 tons. As shown, it is mounted directly over its condenser which is designed to deal with 162,000 lb. of steam per hour, and to maintain a vacuum of 27½ in. when supplied with cooling water at 84 deg. F. In normal duty this water rises to 101 deg. F. in passing through the condenser, so that the ratio of circulating water to condensate is of the order of 37 to 1. The shell is of steel, 9 ft. 9 in. in diameter and the length between tube plates is 16 ft. There are two flows of circulating water which is supplied by a 24 in. centrifugal pump. The head to be overcome is 69 ft., and the pump, which is shown to the right in Figs. 1 and 2, is driven by one of two 500 h.p. electric motors, the other serving as a standby. The tubes number 7,500, and present a cooling surface of 23,500 sq. ft. They are of the Admiralty mixture, and are ¾ in. in diameter by 18 S.W.G. in thickness. The weight of the condenser complete in place is 50 tons. Two 6-in. centrifugal pumps are used to extract the condensate and deliver it against a total effective head of 58 ft. These pumps are driven by electric motors rated at 30 b.h.p. and running at 1,440 r.p.m. The air extraction is effected by ejectors which we shall describe in detail later on.

The generator is designed for a normal output of 12,500 k.w. at 80 per cent. power factor, and supplies 3-phase current at a periodicity of 50 cycles per second and at a voltage of 6,600. Under full load the temperature rise is 40 deg. C., which is attained in six hours, and the machine can carry for two hours an overload of 25 per cent. At this overload its efficiency is 95 per cent., at full load 94·5 per cent., at three-quarter load 94 per cent., half-load 90 per cent. and at one-quarter load 81·5 per cent. The machine is 21 ft. long, 12 ft. wide, and 6 ft. 6 in. high, and weighs 75 tons. It is cooled by a supply flow of 50,000 cubic feet of air per minute, of which one-half is supplied by fans mounted on the generator, and the remainder by a supplementary motor-driven fan 38½ in. diameter which is capable of maintaining the stated flow of air against a water gauge of 10 in. Its speed of rotation is 960 r.p.m. and it absorbs 80 b.h.p. The air is passed through a cooler, which ensures that its temperature on reaching the alternator shall not exceed 80 deg. F. The loss of head in this cooler is equivalent to 1 in. of water gauge. The water flow required is 183 gallons per minute.

A longitudinal section through the turbine is represented in Fig. 3, Plate XLVI, and an end view is reproduced in Fig. 4. The turbine is designed to use steam supplied to the stop valve at a gauge pressure of 185 lb. per sq. in. and at a superheat of 150 deg. F. The condensing water is limited in quantity and is supplied by cooling towers, so that the turbine has "to put up with" the low vacuum of 27½ in. and its steam rate per kw. hour is accordingly some 8 per cent. higher than it would be were the vacuum 29 in., which is now almost a standard figure. The turbine consists of one

Fig. 1.

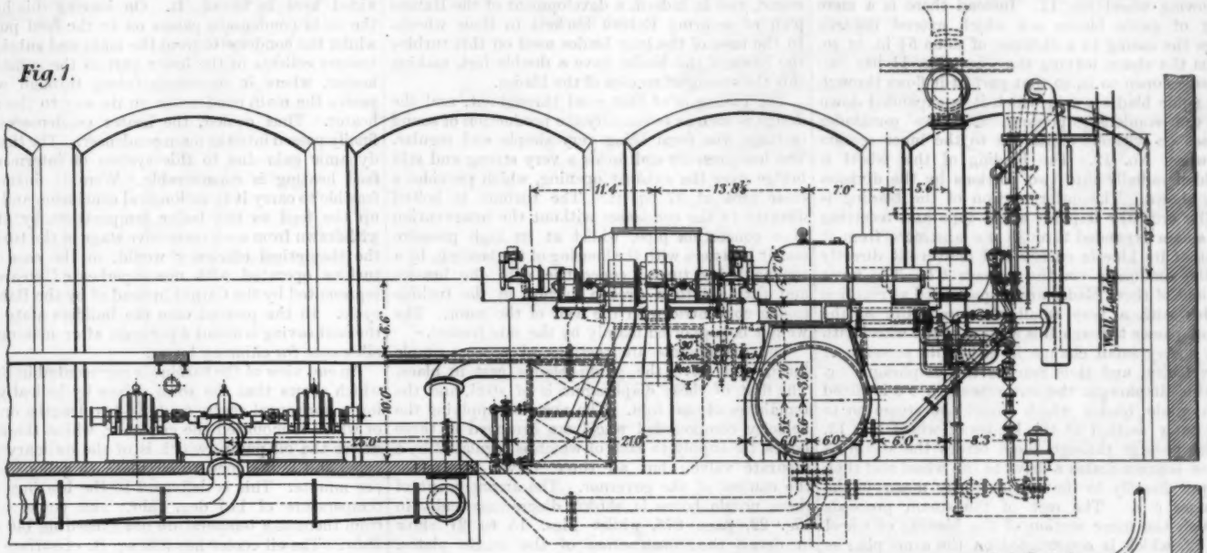
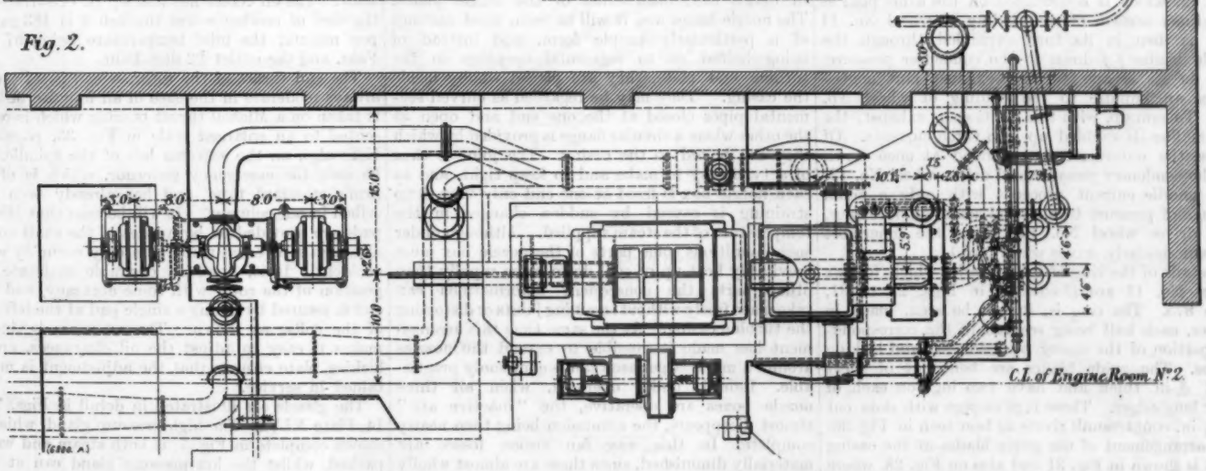


Fig. 2.



velocity compounded stage followed by 10 Rateau stages, and then by a multi-stage exhaust, which constitutes the most striking of the innovations embodied in the design. All stages have the same mean diameter of 42 in., and this with the usual type of design would provide a "leaving" area of some 16 square feet or so, but by means of the multi-stage exhaust an effective "leaving" area of 23·1 square feet is provided for the exhaust, so that the "throw-away" loss to the condenser is as small as if the exhaust end of the turbine were on the double flow principle.

The arrangement will perhaps be best understood by reference to Fig. 3, Plate XLVI. It will be seen that there is no diaphragm immediately following wheel No. 11. Instead there is a mere ring of guide blades *a a* which extend inwards from the casing to a distance of some 5¼ in. or so. Thus the steam leaving the wheel No. 11 has two passages open to it, so that part of it flows through the guide blades *a a* in which it is expanded down to the condenser pressure and the remainder passes on without expansion to the inner section of wheel No. 12. The blading of this wheel is divided radially into two portions by the division ring shown. The outer portion of the blading is of the ordinary impulse wheel type and receiving the steam expanded through *a a* abstracts from it most of its kinetic energy and delivers it directly to the condenser via the passage *b b*. The inner sections of these blades are proportioned as reaction blades with a very small pressure drop, so the steam passes through this section of the wheel with only a very small change in either its pressure or its velocity, and thus reaches the diaphragm *c c*. In this diaphragm the outer passage *c c* is fitted with guide blades which direct the steam on to the outer section of the blades of wheel No. 13. In its passage through these blades the steam as before communicates a drive to the wheel and then escapes directly to the condenser by means of the passages *e e*. The rest of the steam proceeds through the inner section of the blading of wheel No. 12, which is constructed on the same plan as the inner section of the blading of wheel No. 11 and is then in its turn expanded through the guide blades *f f* down to the condenser pressure, and in its escape to the exhaust port contributes an impulse to the blading of wheel No. 14. To sum up, with this multi-stage exhaust, the steam flow is divided up into three currents. Of these the outermost is expanded at once down to the condenser pressure and drives wheel No. 12. The middle current proceeds with only a small change of pressure to a second set of guide blades, and drives wheel No. 13, whilst the innermost current similarly drives wheel No. 14.

Details of the ring of guide blades which follows wheel No. 11 are illustrated in Figs. 23 to 31, page 875. The ring is, it will be seen, made in halves, each half being secured to the corresponding portion of the casing by a dovetail and locking plates. The guide blades are bent out of sheet steel $\frac{1}{16}$-in. thick and have two lugs on each of their long edges. These lugs engage with slots cut in $\frac{3}{16}$-in. countersunk rivets as best seen in Fig. 30. The arrangement of the guide blades at the casing joint is shown in Fig. 31 and also on Fig. 28, where will be seen the special slots for the "half" blades at the joint. It will be noted that the whole arrangement is such that the uniform distribution of the steam is hardly affected by the presence of the joint. The packing strip at the inner edge of this guide blade which checks leakage between the two streams into which the steam flow is divided is shown to an enlarged scale in Fig. 26. The net clearance here as erected is $\frac{1}{16}$-in., but the turbine can without danger wear a larger clearance, should this be required, since the thin edges of the packing strip rub away at a touch and are too slender to deform the heavy parts of either wheel or guide blade ring. Similar packing strips are provided at the other leakage points.

A photograph of the rotor is reproduced in Fig. 32, page 876. The rotor embodies, it will be seen, some unusual mechanical features and makes it possible to build turbines to give very large outputs, at a stated speed, whilst ensuring that the critical speed is well above the running speed. At the exhaust end the "wheels" are very little larger than the rotor shaft, and they are accordingly constructed and secured in a novel manner. They are, in fact, made in halves, and the necessary security against the considerable centrifugal forces is obtained by meshing collars turned on the "wheels" with similar collars turned on the shaft, and riveting the whole together. The plan involves, of course, some drilling which would prove awkward in shops not specially equipped for such jobs, but the builders have long had to undertake similarly awkward drilling operations in connection with the construction of their electrical machinery, and had accordingly the requisite tools handy. Mechanically the construction is very sound, and is, indeed, a development of the Rateau plan of securing Rateau buckets to their wheels. In the case of the long blades used on this turbine the roots of the blades have a double fork making this the strongest section of the blades.

The casing is of cast steel throughout, and the design is such as to simplify the production of sound castings, the form being very simple and regular. The low-pressure end forms a very strong and stiff bridge over the exhaust opening, which provides a clear area of 37 sq. ft. The turbine is bolted directly to the condenser without the intervention of a concertina pipe, whilst at its high pressure end it registers with the housing of the bearing, by a tongue being turned concentric with the brasses and fitting into a groove turned in the turbine casing concentric with the axis of the rotor. The weight is supported mainly by the side frames.

The diaphragms are castings of a very simple form, and have the guide blades cast in place. The first of these diaphragms is of steel, and the remainder of cast iron. The nozzles supplying the velocity compounded wheel are arranged in three boxes, the supply to each of which is regulated by a separate valve; but all three valves are under the control of the governor. The arrangement of these nozzle boxes is shown diagrammatically in Fig. 22, page 875, whilst Figs. 15 to 21 show in detail the construction of the nozzle plates. The nozzle boxes are, it will be seen, steel castings of a particularly simple form, and instead of being bolted on to segmental openings in the turbine end plate, they are placed wholly inside the casing. They may be regarded as curved segmental pipes closed at the one end and open at the other where a circular flange is provided by which they are bolted to the casing. The joint is thus of a type easy to make and to keep tight, and as each nozzle box is fixed at one end only very little straining is caused by sudden changes in the temperature of the steam supplied. Although under such conditions some parts of the nozzle box must inevitably heat up or cool down more rapidly than other parts the consequent deformations can take place freely without straining joints or distorting the turbine casing. At the same time this arrangement has made it possible to extend the nozzles around a much larger arc than is commonly practicable. Indeed, under overload, when all three nozzle boxes are operative, the "inactive arc" almost disappears, the admission being then nearly complete. In this way fan action losses are materially diminished, since these are almost wholly attributable to the "inactive" buckets on the wheel. This is an important point, since the loss under this head depends on the density of the steam, which is always considerable at the first stage of the turbine. The disc friction loss is, of course, unaffected, but as this varies nearly in proportion to the fifth power of the wheel diameter the waste in this respect is remarkably low for a turbine of 12,500 kw. rating, since the mean diameter is but 42 in.

As shown in Figs. 15 to 21 the nozzle plates are each built up of two curved steel angle bars separated at the ends by solid spacers and having the guide blades secured to them by a single bolt as best seen in Figs. 15 and 17. Tipping of the guide blades is prevented by lugs on each of their long edges which fit into slots machined in the angle iron sides of the nozzle plates. It will be noted that the nozzles are wholly convergent, being designed for a speed of efflux about equal to that of sound. Another interesting feature in the turbine is the intermediate feed heater, which is shown clearly at *g*, Fig. 3. It will be seen that some of the steam is withdrawn from the turbine at wheel No. 10, passing direct to the small surface condenser shown. This has a cooling surface of 650 sq. ft., and the condensing water consists of the condensate from the main condenser, which enters the heater at a temperature of about 109 deg. F., and leaves it at 146 deg. F. The steam withdrawn from the turbine to effect this heating is at a pressure corresponding to a vacuum of about 19 in. After leaving this heater the water is passed through the upper part of a second subsidiary heater where it receives a further addition of temperature from steam which has leaked off from the glands, and is accordingly very hot. The surface provided here is 88 sq. ft. On leaving this heater the main condensate passes on to the feed pumps, whilst the condensate from the main and subsidiary heaters collects in the lower part of the subsidiary heater, where it surrounds tubes, through which passes the main condensate on its way to the main heater. Thus cooled, the heater condensates are finally passed into the main condenser. The thermodynamic gain due to this system of intermediate feed heating is considerable. Were it financially feasible to carry it to its longical conclusion and heat up the feed to the boiler temperature by steam withdrawn from each successive stage of the turbine, the theoretical efficiency would, in the case of a turbine operated with non-superheated steam, be represented by the Carnot instead of by the Rankine cycle. In the present case the builders state that the coal saving is about 4 per cent. after making due allowance for chimney losses.

An end view of the turbine is represented in Fig. 4 which shows that the rotor drives by helical gearing a horizontal shaft, made in two lengths on one of which is mounted the governor, whilst the other drives the oil pump, which is of the ordinary gear type, and is designed to circulate 75 gallons of oil per minute. This is delivered to the bearings at a temperature of 115 deg. Fahr., and comes away from them at a temperature not exceeding 140 deg. Fahr. The oil cooler has 330 sq. ft. of surface and the flow of cooling water through it is 183 gallons per minute, the inlet temperature being 87 deg. Fahr. and the outlet 92 deg. Fahr.

The end thrust of the rotor, which is, of course, always moderate in the case of an impulse turbine, is taken on a Michell thrust bearing which is represented to an enlarged scale in Fig. 33, page 876. Here also, on the extreme left of the spindle, can be seen the emergency governor, which is of the firm's standard type, and has already been described in our columns. It will be seen that Michell pads are provided on both sides of the shaft collar, although a reversed thrust can only occur by some accident. It is, however, desirable to locate the position of the rotor with some accuracy, and this end is secured by fitting a single pad at the left side of the collar as shown. The set-screw behind it makes it easy to adjust the oil clearances, and a locking plate ensures that the adjustment is maintained in service.

The glands are illustrated in detail in Figs. 7 to 14, Plate XLVI. The high-pressure gland, which is shown complete in Fig. 7, is both steam and water packed, whilst the low-pressure gland can at will be either steam or water sealed. In each case the water gland is designed to pack against about one atmosphere of pressure, and is thus of moderate diameter. At the high-pressure end the leakage steam through the labyrinth is, as already explained, led away to the subsidiary feed heater. The baffle collars for the steam gland are, it will be seen, turned on a mild steel bush, which is shown separately in Fig. 10, and shrunk into place on the rotor in Fig. 3. It will be seen that for the most part the sleeve stands clear of the shaft, so that should rubbing occur, the shaft proper is unaffected, and in any case, the thin edges of the gland strip, as shown in the detail, Fig. 8, ensure that no serious heating or distortion could be produced, even did the contingency occur. This strip is inserted into the gland shell in lengths, the joints between which are illustrated in the right-hand corner of Fig. 10. As the sleeves are necessarily made in halves, there is no difficulty in putting the strips in place, whilst the form of groove, as shown to an enlarged scale in

DETAILS OF 12,500-KW. TURBINE GENERATOR AT LIVERPOOL.

CONSTRUCTED BY MESSRS. METROPOLITAN VICKERS, LIMITED, ENGINEERS, TRAFFORD PARK.

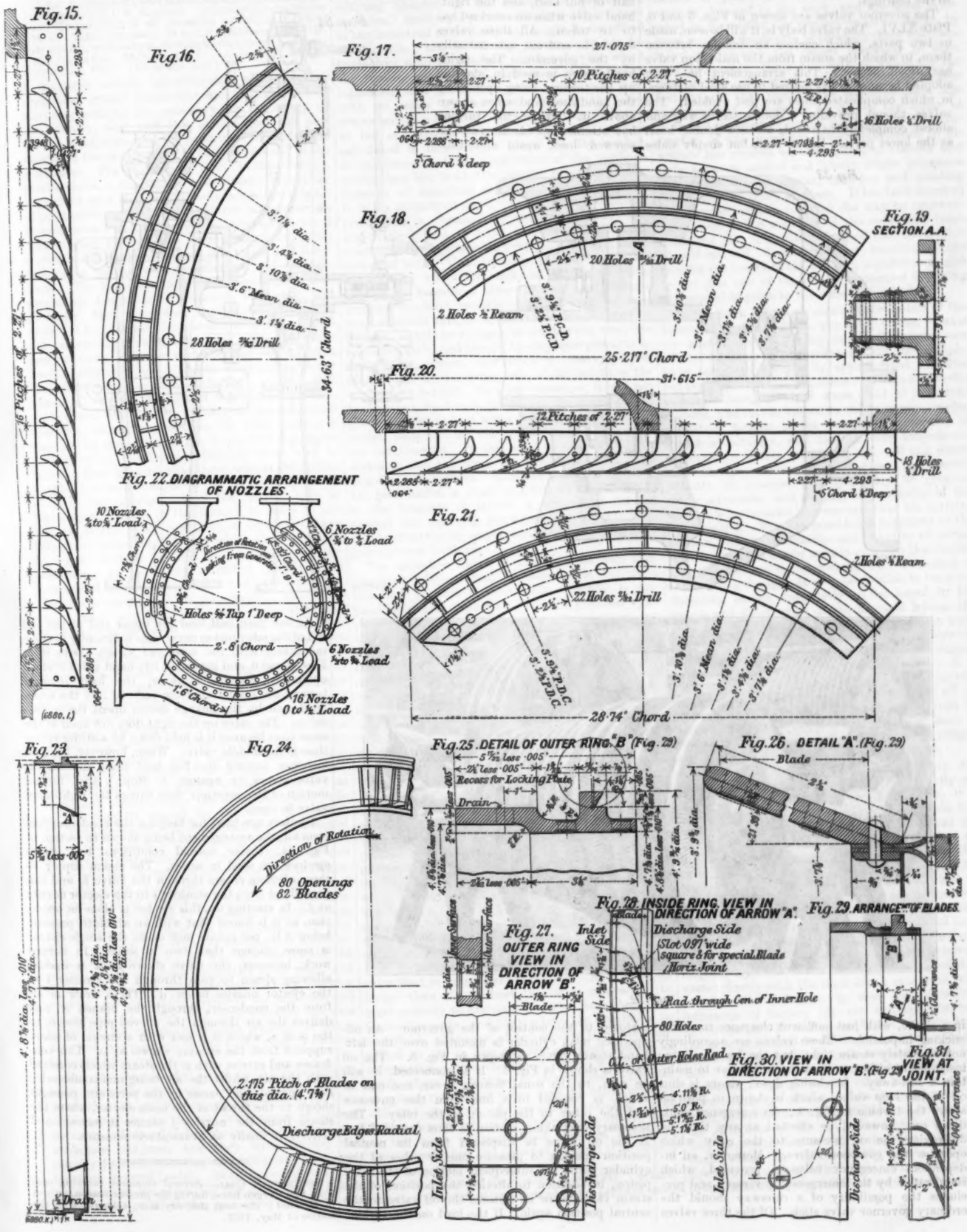


Fig. 7, makes their subsequent escape impossible. Outside of each gland the shaft carries a guard or water thrower, which effectually prevents any leakage from the gland creeping along the shaft to the bearings.

The governor valves are shown in Figs. 5 and 6, Plate XLVI. The valve body is, it will be seen, made in two parts, which enclose an annulus between them, to which the steam from the main stop valve has direct access. This arrangement has been adopted because it was desired to use steel castings, in which complicated cores are best avoided. The valves, though providing a double steam way and almost completely balanced, are not double beat, as the lower portion has no seat, but simply slides in a sleeve, with just sufficient clearance to render sticking impossible. These valves are accordingly not absolutely steam tight, but the leakage is too insignificant either to start the turbine or to maintain a run-away. In closing down, steam is shut off at the stop valve, which is shown in position above the turbine in Fig. 3. An emergency shut-down can, however, be effected at any time by destroying the oil pressure to the relay which operates the governor valves. Moreover, an independent emergency valve is provided, which is operated by the emergency governor, and precludes the possibility of a runaway should the ordinary governor valve stick. Of the three valves shown in Fig. 5, that on the left feeds the lowest of the nozzle boxes, and alone supplies steam when the turbine is running at half-load or under. The middle valve opens when the load rises above one half of full load, and the right-hand valve when an overload has to be taken. All three valves are cut in and out automatically by the governor. The right-hand valve is used in starting up the turbine, being opened by the handwheel and screw shown above it. When the turbine has attained speed, the valve is screwed back again and thus restored to the control of the governor. An oil-operated relay cylinder is mounted over the left-hand steam valve, as shown in Fig. 5. The oil valve is shown in Fig. 6. It is connected, it will be seen, to the usual floating lever, one end of which is coupled to a link from the governor and the other to the piston of the relay. The necessary overtaking motion is thus provided for. If the oil valve be displaced from its neutral position opening to pressure one or other of the cylinder ports, the subsequent motion of the relay piston, in addition to altering the position of the steam valve below it, restores the oil valve to the neutral position again. If the load on the turbine is suddenly thrown off, there is a momentary rise of 5 per cent. in the speed and a permanent rise of 3 per cent. after steady conditions are again re-established.

Fig. 33.

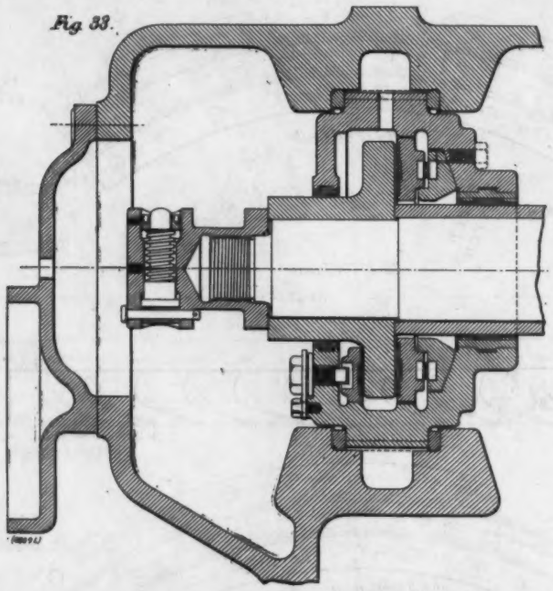
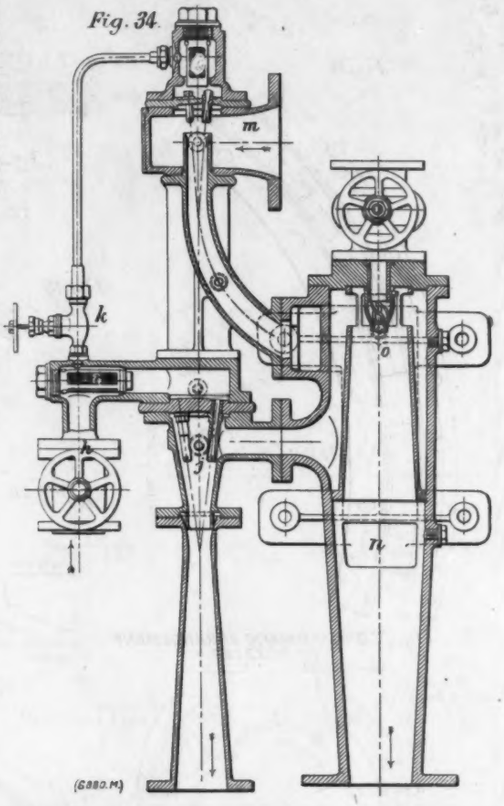


Fig. 34.



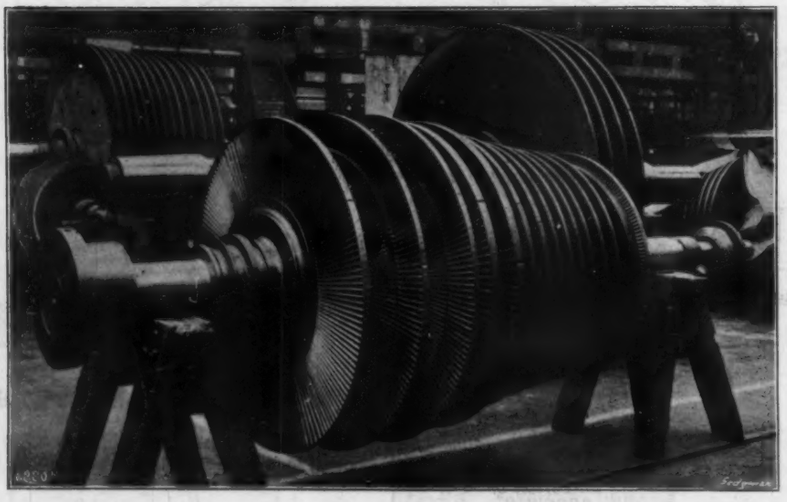


Fig. 32.

At less than half load the upper end of the tail rod of the relay piston never rises sufficiently to come in contact with the crosshead shown above it in Figs. 5 and 6, and hence the left-hand valve is alone operative. Should, however, the load increase beyond the limit stated the tail rod lifts the crosshead, and by the linkage shown opens the middle valve. The valve on the right does not open at the same time because it is held down by a stiffer spring than is the middle valve. When, however, the load increases beyond the full load limit the middle valve comes up against a stop. Any further motion of the governor then causes the right-hand valve to open.

Ejectors are used for keeping the condenser free from air, the arrangement being shown in section in Fig. 34. Under normal conditions two steam ejectors are used in series. The steam supply to these ejectors enters through the valve *h*, and can pass direct from the strainer *i* to the ejector nozzles at *j*. In starting up, this ejector is alone in operation, as it is found that with an absolute pressure below 8 lb. per square inch or so, the single ejector is more efficient than two in series. In normal work, however, the valve shown at *k* is opened allowing steam to pass through the strainer *l* to the ejector nozzles below it. These draw in air from the condenser, through the branch *m*, and deliver the air through the curved pipe shown, to the port *n*, where it is met with a stream of water supplied from the sprayer shown at *o*. This condenses and carries with it the steam which is mixed with the air, whilst the air being non-condensable rises upwards and passes by the ports and passages shown to the throat of the main ejector, where the steam from the nozzles *j* carries it forward and delivers it finally at atmospheric pressure.

Spitzbergen Coal.—Several steamers carrying coal from Spitzbergen have, during the present season, arrived in Holland; the next delivery is to take place in the course of May, 1922.

LITERATURE.

The Health of the Industrial Worker. By EDGAR L. COLLIS, B.Ch., M.A., M.D. (Oxon), M.R.C.P. (London), M.R.C.S. (England), and MAJOR GREENWOOD, M.R.C.P. (London), M.R.C.S., England. Containing a chapter on the Reclamation of the Disabled by Arthur J. Collis, M.A., M.D. (Cantab), M.R.C.S. (England), D.P.H. (Durham), with an Introduction by Sir George Newman, K.C.B., D.C.L., M.D., F.R.C.P. London: J. and A. Churchill, 1921. [Price 30*s.* net.]

A WARNING outcry, heard through many avenues, urges that greater production and enlarged manufacturing activity are necessary for the safety of the country, and with this lament goes the plea for the amelioration of the conditions of life for the masses of the people, both in their homes and in the workshop. The whole social fabric in this country, as elsewhere, is threatened with disaster, unless the important part that labour performs in the scheme of production is more fully recognised and rewarded. Revolutionary methods must be introduced into a system that hitherto has been content to utilise strength and muscle, but will not brook any interference or control with organisation and management. The long-suffering proletariat complain that machinery has achieved so much, obediently and tirelessly, that the same mechanical routine is expected from those who watch and feed its relentless activities. Exaggeration may mark the utterances of some, but more and more the fact is forcing itself on public notice that the determining factor in industry is the human factor. "The 19th century," say the authors of this admirable work, "discovered the value to industry of the inanimate machine; already we can see the 20th century is discovering the value of the living and intelligent human being." Whatever different views may be taken of the argument, that those, who at the polling booths are held competent to be trusted with a share in the management of the Empire, may at least equally claim in the factory to share in the control of the lesser organisation that they have helped to make possible and which they maintain by their exertion, it will be admitted that the workman, as a finely adjusted physiological instrument, makes a contribution of quite a peculiar kind, the expression of his personality. The wider use of machinery in adding to our material advantages has also increased the difficulties of existence, by aggravating the evils arising from imperfect hygiene and overcrowding. The habits peculiar to factory life, among which figure the fatigue due to monotonous occupation and the depressing influence of the surroundings in which men and women are made subservient to the demands of exacting machinery, add their quota to the special hardships and sacrifice to which labour is required to submit. "Human progress," says Lecky, "rarely means more than the surplus of advantages over evils." This may be true in regard to the community at large, but unfortunately the advantages and evils are not equally shared by the same individual. The problem before the statesman and the scientist alike, is to show how that surplus can be increased and evenly distributed. A certain degree of well being and the prospect of increasing it is the indispensable basis of civilised life, for the growth of prosperity alone assures to everyone the chance to be human. To share in the stock of good things, which it rests with ourselves to increase, is the only way to prevent the chaos of discord and annihilation. The destruction of war has diminished the margin which separates prosperity from want, and in the alarm and unease occasioned by growing anxiety, we are asking ourselves for remedies and examining the causes that have retarded the rate of production, on which depends, whether we admit it or not, our progress on the toilful road of civilisation and improvement.

The contribution of the authors to this problem is both valuable and well defined. They aim at exhibiting the profound changes wrought in the lives of the people by the rise and development of modern industry. This subject is too large to treat within a moderate compass, and they have limited the inquiry to demonstrating the influence of employment on general health. Both have enjoyed wide opportunities for observing the problems of industrial hygiene, and having perceived the numerous opportunities presented in industry for studying the forms of disease, that are the effect of divergencies from health, and also of detecting the means for improving the workaday life of the productive classes, offer a mass of evidence that constitutes an edifying chapter in the history of preventive medicine. Such a purpose is entirely in the interests of the industrial community and might be described as altruistic; but Sir George Newman in his introductory note emphasizes another purpose which the treatise might fulfil, and one, though quite legitimate and justifiable, that might not meet with so ready an acceptance among the class whose benefit is sought. While admitting the value of the suggestions and sound practical advice calculated to improve the health of the worker, he intimates that the application of the methods would place him in a better position to render a fuller measure of industrial service to the community. It is an undoubted truth that the most economical production is obtained by employing those who are at their best in mind and body, and under circumstances in which they can yield the maximum output of both. Unfortunately, there are too many instances in which the workman objects to being trained to become a more perfect and efficient working machine, capable of performing the same work with less fatigue and less exertion, because he believes, rightly or wrongly, he will have to complete a heavier task, and benefit his employer proportionately. His narrow view stops at the employer, he does not see the larger issue of the benefit to the community behind. In many instances, it will not be disputed, the hourly product of the workman has grown smaller than it was a few years back, though health, capacity, and the appliances of labour have not deteriorated. In this work of amelioration so desirable and uplifting, the workman is often an unwilling co-operator. The policy of "ca' canny" has been hailed in many quarters as the safeguard of the interests of labour, a weapon of defence against the exacting employer, and a charitable means of extending employment to weaker and more incompetent brethren.

The mistaken views of short-sighted and half-educated advisers find no support in the facts collected in this volume. The attitude is dispassionate and impartial. Though personal sympathy with the suffering is neither hidden nor obtruded, it is not allowed to influence the judgment that follows thorough and patient inquiry. The direction in which improvement might be effected may appear clear and decisive, but experience teaches that the obvious is usually wrong or misleading. Conclusions must be supported by facts not by sentiment; zeal is neither permitted to distort what is favourable nor to obscure what is detrimental. In this calm investigation, therefore, great use will be made of statistical methods, and the tables of mortality are relied upon to furnish trustworthy information concerning the sanitary status of trade and occupation. Death rates are not unerring guides in industrial inquiries; morbidity, which can operate very disastrously on production, does not necessarily pursue a parallel path with mortality. Sickness may be frequent and wasting, without being fatal, and some occupations afford instances of high sickness concurrently with low rates of mortality; but the uncertainties that tell against accuracy, or increase the difficulties of interpreting statistical information are well known, and must be allowed for as far as possible, though they be of such a character that they cannot be submitted to numerical calculation. No one knows better than the authors that it is misleading to trust entirely to the data provided from Registrar-General reports, and they admit the unreliable or unsuitable character of the figures they are compelled to use in the absence of other sources of information. The theory of errors is an unsafe guide where the number of observations is limited, or where systematic errors may be introduced by different methods of collecting evidence. The theory demands that the observations should refer to the same unknown, and this can hardly be guaranteed when the personal element is so largely involved.

No discussion of the relative "weights" attaching to the observations is made and perhaps none is possible, but the remarks on the "Reliability of Data" may undoubtedly be read with advantage. Statistics may reveal the existence of some causes operating adversely to the interests of industrialism, they cannot detect the contributory causes or point to a remedy. Those who are actively engaged in the work, and are most interested in increasing the productive power, seem, by some perverse destiny, to be precisely those who have failed to perceive the causes operating to their own detriment. Some obliquity of vision on the part of the employers has led them to oppose factory acts that would have benefited them and the capitalist, reluctance to curtail the hours of work has diminished output and added to the discomfort of the operative, while indifference to his welfare has created an atmosphere of rancour and envy between capital and labour, whose poisonous effects are still hampering industry and creating conditions that delay progress. It has been reserved for informed science to point the way to improvement, and find a solution of the evils that beset industrial life. Physiologists, freed from the meshes of self-interest, declare without hesitation, that care for the health of the working population should be the first aim of those most concerned in giving the needed impulse to the wheels of industry.

In the book before us, some of the causes of the failure of health and the way these causes operate are made clear to the lay mind. The pernicious effects of fatigue on the human system, for example, have not been adequately apprehended hitherto, but the neglect of the symptoms exercises a powerful influence throughout the whole field of industrial hygiene, and can be traced in the economic results. Industrial fatigue is the sum of the results of industrial activity, and can be only imperfectly measured by bodily sensations, nor will any direct test, though various devices have been tried, indicate its amount. Fatigue may be progressively advancing and sapping the capacity of the worker, who remains unconscious that his activity is decreasing. It is the considered judgment of the authors, that in the quality and quantity of output is to be found the only certain criterion that health and activity are being maintained. Possessed of this guiding thought, it may be possible to trace the operating causes, frequently to be found in the length and distribution of the hours of labour, the varying condition of factory life under which work is carried on, and the methods of employment practised, when the appropriate remedy will suggest itself. To enter into details is impossible; it is sufficient to point out that competent authorities are examining the problem of fatigue in all its bearings, that those who are anxious to profit by the teachings of science and experience can have all the aid they require, and that the hopes of escaping from the errors of the past can be encouraged.

Pulmonary tuberculosis and cancer are two diseases that are considered both statistically and industrially. With regard to the former, it is satisfactory to note that the evidence points to a diminished rate of mortality. This essential fact may be regarded as established, as also that the death rate among women has decreased faster than among men. The causes that have produced this distinction between the sexes are obscure, and the inferences drawn, though plausible, require confirmation from more extended data than are at command. Statistics, fragmentary as they are admitted to be, show, however, that when male and female industrial employment is at a maximum and minimum respectively, the index of bad home conditions varies closely with the male death rate from tuberculosis. The inference is that the deleterious influences of factory life act through the home environment. It is suggested that the vitality of the male is lowered by factory conditions, rendering him more susceptible to evils associated with home life. Other hypotheses might be weighed and examined. Cancer, on the other hand, is growing more fatally prevalent, and in its incidence differs from tuberculosis—which strikes its victims when the activities of life and the metabolic changes they represent are in full swing—by manifesting itself when the vigour of life wanes, gathering strength as activity diminishes. How far modern industrialism is responsible or explains this unwel-

come increase is uncertain. The absence of sufficient data to warrant a decisive conclusion is lamentable. The authors hold, as the result of their impartial examination, "that the sudden change which has taken place in the conditions of life consequent upon the development of modern industry has been associated with a rapid rise in cancer mortality, and this rise is greatest where modern industry is most developed." A simple coincidence in time may explain some of the observed connection. If correlation had been sought between other factors, similar relations might have been detected. We doubt if the words "associated with," implying intimate connection, are justified.

An interesting chapter on accidents leads to a surprising conclusion, that makes one question whether the method of investigation takes cognisance of all the contributing factors. The authors emphasize the conclusion that, though the circumstances attending accidents are known, and microbic influence and hypothetical variations in the potency of epidemic attack are eliminated, yet the incidence and frequency of accidents show distinct points of resemblance with those of diseases attributed to biological influences. "In the physiological and psychological condition of the worker and in his reaction to the conditions of his environment lies the origin of the vast majority of accidents," and it is pertinently asked whether other forms of disease and mortality may not similarly depend, far more than is at present appreciated, upon the physiological and psychological condition of each individual. The natural corollary follows that the most promising way of attacking the incidence of sickness and premature death is to be found in the maintenance of personal health and the cultivation of resisting power, rather than by attempting to fence the public about with protective guards against disease.

The general introduction of mechanical power having rendered possible the employment, on a large scale, of women in industry, this topic in its social and economic aspect is brought into bold relief. No nation can afford to leave the energy of half its population unused, and the problem of taking the fullest advantage of this energy is a large one. The authors' examination shows that woman has ever been a labour-sharing colleague with the male, that she has not functioned simply as a mother and a nurse of children, and that her work in modern industry is not more onerous than the physical labour to which she has been accustomed through the centuries. It is contended that the employment of woman has been beneficial, and cordial support is given to the opinion of Havelock Ellis in his assertion, "that the hope of our future civilisation lies in the development in equal freedom of both the masculine and the feminine elements in life. We are not at liberty to introduce any artificial sexual barrier in social concerns. The respective fitness of men and of women for any kind of work or any kind of privilege can only be ascertained by actual open experiment."

After this it would be an anticlimax to discuss the feeding of the industrial worker, the provision of adequate ventilation, the effects of humid atmospheres, sanitation, welfare work and other matters touching factory life, subjects to which the authors devote much thought and space. This does not mean that these matters are unimportant. The details given are many and precise and their necessity and importance are universally admitted. The last chapter on the "Reclamation of the Disabled" is by Dr. A. J. Collis, and is of a rather professional character, but lends completeness to a thoughtful work, that will be much appreciated by those who have at heart the interests of industry and the nation.

Aggregation and Flow of Solids, being the Records of an Experimental Study of the Micro-Structure and Physical Properties of Solids in Various States of Aggregation. 1900–21. By Sir George Beilby, F.R.S. Macmillan and Co., Limited. [Price 20s.]

The molecular structure and physical properties of metals and solids have long engaged the attention of Sir George Beilby, but the extent of his inquiries and the success of his investigations can only be fully realised from the present volume, in which are presented as a consecutive whole the results published from time to time on the completion of some particular research. Such a collection and resifting of earlier work, not only has the advantage of exhibiting the present state of our knowledge, but prevents the repetition of researches being prosecuted on the same lines, in ignorance of the experimental evidence already obtained. Inquiry into the minute has been pushed much further than was contemplated when this work was begun, and other means of experiment have been devised, but the value of these early investigations remains unimpaired. The microscope was the most powerful instrument at the command of the author, and in his hands it has proved effective and trustworthy. The beauty of the microphotographic reproductions give evidence of both the effectiveness of the instrument and its admirable manipulation. Those who have used the microscope to the limit of resolution, know and mistrust the deceitful appearances encountered when attempting to unravel mysteries concealed within the compass of a wave length of light, and since many of the measures referred to are of much smaller dimensions, they will appreciate the description which Sir George gives of his method of working and control.

In the earlier chapters are traced the effects of surface tension on thin films of metal in the solid state, and the formation of solid aggregates by the mutual attraction of molecules. For observing the effects of surface tension, films of gold, silver and platinum, varying in thickness from a few millionths of a millimetre up to that of ordinary gold leaf, were deposited on glass and mica plates. The thicker films showed clearly the effects of surface tension. Under the microscope the forms assumed by the gold films resembled the transient forms which are seen in an oil film on water. The repetition of the same type of figures on thinner films, or where the contraction of the opaque and more massive figures on the thicker film had left a thinner film on the glass, showed that the molecules had been in a state of free movement under the influence of surface tension.

Another series of interesting experiments exhibits the effects of cohesion and vibration of individual molecules in determining the form of molecular aggregates. The process is carefully traced in the phenomena of crystallisation, following the withdrawal of heat energy, and here it is noted, that if the passage from the liquid to the solid state is accelerated by sudden chilling before the crystalline arrangement of the molecules is complete, some of the substance is fixed in a vitreous amorphous condition, and the aggregate attains a structure not in accordance with that of the normal crystalline state. This, we believe, to be the earliest recognition of the generation of amorphous metal, which under the operation of internal stress may prove sufficient to pull the constituent crystals asunder. The experiments formed the beginning of important work on plastic straining and surface polishing, to which Sir G. Beilby subsequently devoted so much attention. At this stage, however, the author considers mainly the form and texture of solid aggregates at the surfaces of contact of gases with gases, gases with liquids and solids, and of liquids with other liquid and solids. These operations, minutely described, afford a very fascinating subject of microscopic study, while the further pursuit of the subject into cohesion among minute solid particles, and cohesion between such particles and flat surfaces, leads to some unexpected results. In the cohesion tests, an attempt was made to determine the area of contact between minute globules of gold and the glass surface on which they were deposited, or to which they were suspended. This area approached a geometrical point, for "even with lenses of the highest resolving power no surface of optical contact between the metal and the glass could be detected. The largest globule of gold that remained attached to the glass had a diameter of 0·113 mm., and a weight of 0·0000147 gramme. On some plausible assumptions of the area of contact, the weight supported varied from the equivalent of 1 ton to 23 tons per square inch.

From the general phenomena of surface tension and assumed forms of aggregation under various conditions of mobility, the author directs inquiry into the particular kind of mobility conferred on the molecules of a solid by forms of mechanical disturbance and by the processes of cutting, grinding and polishing. As is well known, he has demonstrated that in every case when a substance is sufficiently homogeneous to be polished at all, the only explanation permissible is that the polished surface is entirely due to the presence of a surface tension skin. The general idea that the essential feature of polishing was the gradual flattening of the surface by the removal of material is true when applied to grinding, but is not an accurate description of the change effected by polishing. The series of photographs showing the process by which a scratch on the surface of speculum metal is removed, demonstrates clearly the manner in which a definite layer is spread over the surface. A suitable abrasive as a rouged leather is seen to have seized the upper layer of molecules and pulled it over the surface like a skin, filling up and bridging over the inequalities produced by the scratch. This layer, which is essentially different from the general body underneath it, can be removed by the action of a solvent, disclosing the crystalline structure below. The suggestion is made and supported by experiments on a great variety of substances, that the surface layer had for a brief period been in the liquid condition. Apparently no crystalline substance is too hard to yield to this mechanical flowing action. Step by step removal of the surface layers from a plate of calcide by HCl, discloses the nature and extent of the disturbance of those layers. It is shown that ploughing and breaking up of the lamellæ can occur to a depth of from 500 $\mu\,\mu$ to 1,000 $\mu\,\mu$. Incidentally it may be mentioned that a roughening of the surface not more than two molecules in depth has been detected. This depth is equal to 0·62 $\mu\,\mu$ ($1\,\mu\,\mu = 10^{-6}$ mm.).

Further deductions from the theory of polishing suggest the hypothesis that the hardening of metals results from the formation of mobile layers at all the internal surfaces of slip and shear. These layers only retain their mobility through a very brief period, and then solidify in a vitreous state, forming a cementing material at all these surfaces, a process which has the effect of binding the crystals into a structure of greatly increased rigidity. The effects of this change of state on the chemical, electrical, acoustical, optical and mechanical properties are very fully discussed. The experiments and deductions point to the presence of a condition of strain, which has important industrial applications, in affording a possible explanation of "fatigue," and the apparently spontaneous fracture of finished articles of manufacture. It has been asserted that fracture will occur under the prolonged application of external stress; when no plastic strain has contributed to the formation of an amorphous metal cement. In such cases, the gradual separation of the crystals along their original boundaries must be effected by other means, but the explanation of Sir George Beilby is satisfactory under the conditions he has demonstrated to exist.

The theory of flow is further applied to the behaviour of rocks and ice, and the conclusion is submitted that the theory based on the fusion of ice under pressure and its regelation on the removal of this pressure, is inadequate to explain the formation and flow of glaciers. When applied quantitatively it is seen that greater forces are needed than exist. Such phenomena do exercise an influence on the behaviour of glaciers, but the conditions do not cover a sufficiently wide range to justify the universal application of the theory. True molecular flow which is not confined to the external portions, but takes place at the internal surfaces of crystalline aggregates, is a more potent agent than fusion and regelation in bringing about the movement of glaciers.

The concluding chapters are directed to inquiries into the optical characteristics of thin metal films, and the phosphorescence of crystals produced by a change from the crystalline to the vitreous state. In the former some of the conclusions of Faraday, presented in the Bakerian lecture, on the "Experimental Relations of Gold to Light," are examined and challenged. Faraday's method of obtaining a thin film of gold was to float it on a dilute solution of cyanide of potassium, and he assumed that the action of the cyanide was to eat away the surface uniformly. The action of the cyanide, however,

is to dissolve first the vitreous metal, penetrating right through the substance of the leaf, "so that the attenuated film, which remains, is a skeleton built up of the minute units of the crystalline phase, which have survived the severe ordeal of beating." For Faraday's purpose it was necessary to determine whether the transparency and colour of gold leaf were genuine and intrinsic, and the experiments confirm the contention of Faraday. Similarly, the assertions that gold leaf becomes transparent when heated to a temperature of 500 deg., and that the original green colour can be restored by burnishing, are also corroborated. The explanation given by Faraday is not accepted. He suggested that the changes due to pressure and heating were attributable to a certain mechanical subdivision into films of the metal, "the beaten leaf being like a Venetian blind with its louvres closed, the effect of heating being to open the louvres so that light can pass through freely." The observations and experiments of the author indicate that the transparence in the annealed leaves and films results from "open formation" in the molecular, not in the cruder mechanical sense, and this view has been confirmed by the mathematical investigations of Mr. J. M. Garnett. Of the second investigation, tracing the forms of phosphorescence to the passage from the crystalline to the vitreous state, or from one vitreous state to another, space will permit only the recapitulation of the author's conclusions. Three distinct types are recognised, first, those due to molecular movement or displacement caused by heat, by mechanically applied stresses, or by radiant energy. A second type can be traced to atomic changes in which chemical affinity is the controlling factor. There is a third type, in which apparently the products of a species of electrolytic association are insulated from each other by the neutral molecules, as in a viscous electrolyte, "and that it is the breaking down of this insulation and the recombination of the ions which cause revived phosphorescence."

The book is one of singular interest, the experiments are described so clearly that one can almost take part in them. Many hypotheses are raised that compel attention, whether we yield a full assent or not, and we are under an obligation to Sir Herbert Jackson and other friends, who persuaded Sir George Beilby to present his arguments in a connected and attractive form, supported by selection from many excellent microphotographs.

Automatic Telephone Systems. By WILLIAM AITKEN, M.I.E.E., A.Am.I.E.E. Vol. I. *Circuits and Apparatus as Used in the Public Services.* London: Benn Brothers, Limited. 1921. [Price 25*s.* net.]

THIS is a book written by an expert for the use of experts, and its aim is to explain the mechanism employed in the various schemes designed to substitute automatic arrangements in the place of manual switching, now in general use in telephone communication. That greater efficiency and economy will follow the adoption of automatic mechanism may be admitted, and its general use will go far to meet the demands of the public for a more prompt and accurate service, than is possible under the manual system which has rendered good work in the past, but is not capable of adequate extension. The traffic growth in large multi-office exchanges, and the various and complicated services required, introduce difficulties which are increased by the insufficient supply of a good class of operators, owing to the greater demand for the services of women in other branches of industry. Fortunately, the suppression of manual labour, either partially or completely, can be readily effected. Automatic switching has long past the experimental stage, and has proved itself capable of meeting all the conditions of modern business and social requirements. Financial difficulties will occasion delay in installations, and doubtless some hesitation is caused by the possibility that later and improved designs will render obsolete the earlier adopted. Some risk has to be taken, and at once, but the author, an ardent advocate for the adoption of automatic telephony, points out that the problem is in a more unstable condition to-day than at any period in the past. This, however, is the natural consequence of experts who, recognising the advantages possessed by the method in its untiring activities throughout 24 hours of the day, its reliability, its exactness and correctness of operation, its capabilities for meeting abnormal rushes of traffic, have redoubled their exertions to improve and simplify the necessary mechanism. We are far from any effective method of "standardisation," but that is inevitable, and an evidence of progressive improvement.

Meanwhile it is necessary to train electrical engineers and to provide them with the necessary equipment to meet new developments, and for this purpose this manual has been prepared. The method of explanation adopted is unusual. Greater weight is attached to the diagrams than to the letterpress. Lengthy description of the various parts of the apparatus is avoided, and the method of operation of very complicated mechanism is indicated by diagrams, constructed on a special method devised by the author permitting each circuit to be traced throughout. The circuits are taken in the order of operation, and numbered progressively, so that the expert can read the diagram with only an occasional reference to the text, the main purpose of which is to furnish the student with the means of following the particular devices employed and their functions. These diagrams may be compared to a collection of mathematical formulæ, which, at first unintelligible to the beginner, by degrees recommend themselves by reason of their precision and conciseness. The format allows these diagrams to be drawn on a comparatively large scale, thus making them clear to the initiated, but some considerable practice is needed before using these plans easily.

Having mastered the method of delineation the variations adopted in the different schemes for automatically connecting one of the group of lines to any other in the same group becomes a very interesting study. The main principle by which an idle line of a group is selected automatically is well known, for the Strowger system has been often described and has been in active operation since 1889. In this country alone, the Strowger system has been on trial in several towns, as Leeds, Portamouth, Blackburn and some smaller exchanges. It is not a little remarkable that this system, in which the fundamental switch is a vertical and rotary stepping switch for 100 lines, with 10 levels and terminals for 10 lines in each level, has not made more progress. Much ingenuity has been exhibited by Mr. A. E. Keith in devising improvements, and the plan is thoroughly trustworthy. Mr. Aitken explains the comparatively backward position as due to the opposition offered by the "Bell" interests, which in some instances acquired the automatic installations erected by the Strowger Company, of Chicago, and allowed them to fall into disuse. These tactics are to be deplored, for much valuable experience has been lost, and the United States have failed to give that decisive lead which would have encouraged the wider adoption of automatic communication. But the Strowger device has been the parent of other methods, which differ only in detail: For instance, the Siemens Brothers' system, which is operating successfully, departs from the original scheme mainly in using an individual rotary switch with each subscriber's line, separating the relays from the selector mechanism mounting frame, and in the manner of selecting an idle line of a plurality to subscribers' offices.

The Western Electric Company, operating in connection with the American Telegraph and Telephone Company, have made considerable advances, and now have in practice two systems which possess distinct features, one known as the Rotary switch and the other as the Panel system. The former uses a 200-line switch with 10 levels of 20 sets of line terminals and 10 sets of wipers or brushes, one set being tripped into engagement when a line is called. A characteristic mechanical feature in this form is the power drive; a small motor driving the shafting so that it is rotated continuously. Power thus taken from continuously-running shafting, permits the use of heavier and mechanically stronger switches, admitting of greater pressure between the brushes and the contacts than on other systems. The switches can be used at the most efficient speed, and the comparatively heavy brush carriages are set readily in motion, when they are driven with a smooth continuous motion that avoids all vibration and jarring.

The panel system of the company claims many advantages, and as one of the latest forms has profited by the experience of the others. The fundamental method of operation is the same as in the rotary system, and its recommendation is that it is particularly suited to large networks. Emphasis is laid on the fact that the panel system permits the use of trunk groups of any size up to 100. It is announced, that the Post Office proposes to install a trial exchange office on the panel system in South London, in the building containing the present Central and City offices. The equipment will take all new lines in the area, relieving the present manual switchboards, but should the trial prove successful, the existing equipments will gradually be replaced, and the general system be extended. The arrangements for a 500-line panel switch are given, but the circuits of the commercial system are not yet available, and the author has utilised the patent specifications for reproducing the diagrams. It is expected that the details will be available for a second volume, which is promised, and will be readily welcomed.

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PROPOSED CANTILEVER BRIDGE AT SYDNEY, NEW SOUTH WALES.

During the past forty years much discussion has taken place and many proposals have been considered by the authorities in New South Wales for providing suitable means of communication across Sydney Harbour to accommodate the growth and development of Sydney. Public tenders and designs have been invited, and awards made for the best proposals submitted on several occasions, but no definite steps have been taken to carry out any of them. Low and high-level bridges, floating bridges and tunnels have been investigated and postponed. The development of which has since elapsed some modifications would appear to have been introduced.

Tenders and designs are now invited by the Department of Public Works, New South Wales, for the construction and erection of a cantilever bridge from Dawes Point to Milson's Point, carrying four lines of railway, a main roadway 35 ft. wide between the kerbs, a motor roadway 18 ft. wide, and a footway 15 ft. wide across Sydney Harbour with approach spans, having a total length of 3,816 ft. centre to centre of abutments. The headway required for shipping will be 170 ft. at high water for the central 600 ft. of the bridge. The bridge is to consist of steel cantilevers spaced 98 ft. 6 in. apart centre to centre, with shore and

Fig. 1. PLAN OF SITE, SYDNEY HARBOUR BRIDGE.

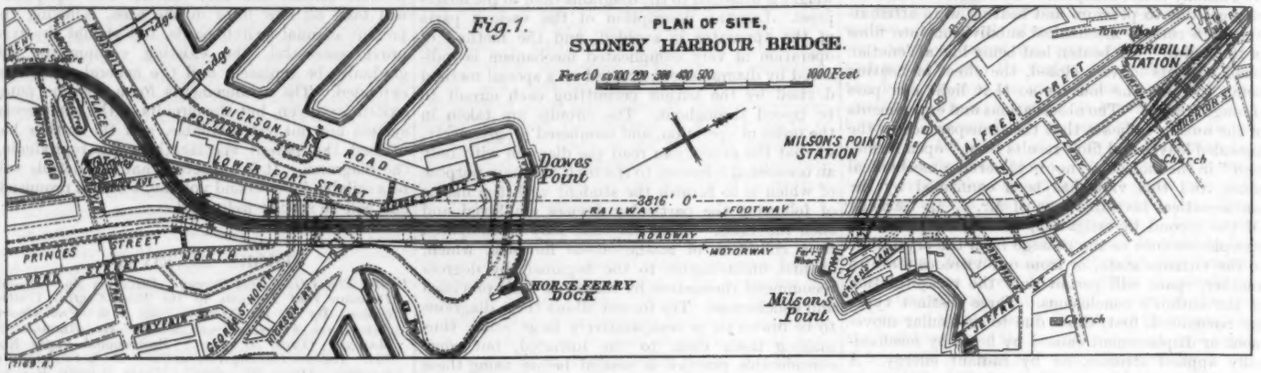


Fig. 2.

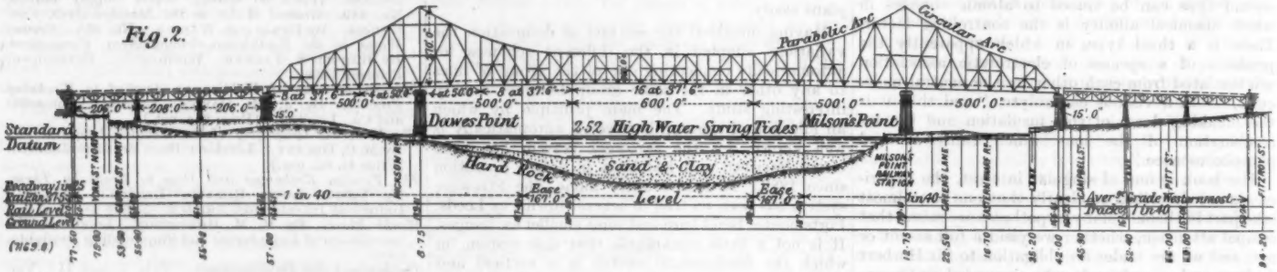


Fig. 3. CROSS SECTION.

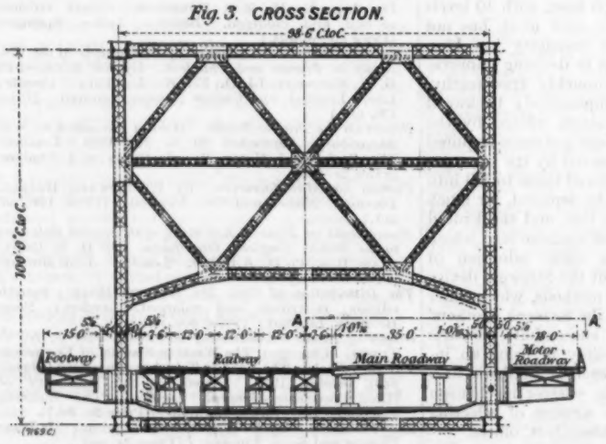
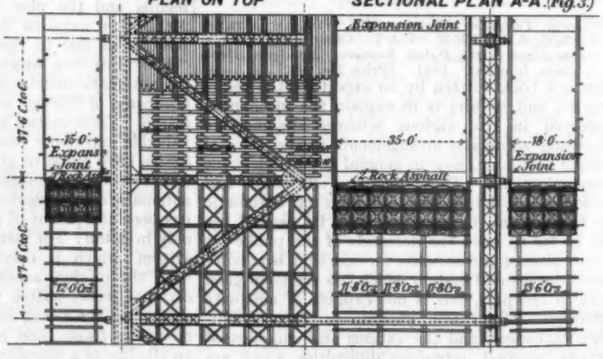


Fig. 4. DETAILS OF SUSPENDED SPAN.

PLAN ON TOP SECTIONAL PLAN A-A (Fig. 3.)



Sydney has proceeded, and sites, formerly suitable, had to be abandoned, and new and more costly schemes considered.

The decision of the Government to adopt a bridge, in preference to other means of crossing the harbour, was arrived at after a report had been submitted on the subject by Mr. David Hay, M.Inst.C.E., of Messrs. Mott and Hay, of Westminster. This report we dealt with in detail at the time of its publication in 1913 (vol. xcv, page 675), when we gave a map of Sydney showing the point of the crossing, and profiles giving the grades involved by bridge and tunnel projects. This report was accepted by the Government, and a few months later, in our issue of December 12, 1913 (vol. xcvi, page 800), we were able to give full particulars of the accepted design for the proposed bridge, the plans of which had been worked out by Mr. J. J. C. Bradfield, M.Inst.C.E., chief engineer of Metropolitan Railway Construction, Public Works Department, N.S.W. The article referred to will be found to give a number of interesting details, though in the interval harbour arms, each 500 ft. long, the harbour arms supporting a central span 600 ft. long. The clear span from centre to centre of the main piers will be 1,600 ft.

The cantilever and suspended span is shown in the accompanying elevations, plan and sections (Figs. 1 to 4), has "M" bracing, and each panel is divided into four members, having cross-girders pitched 37 ft. 6 in. and 50 ft. apart centres. The cross-girders are cantilevered out beyond the main girders to carry the motor roadway and footway.

Each of the three spans on the southern approach consists of four "M" type deck trusses with sub-divided panels, 204 ft. long, centre to centre of end posts, and spaced 30 ft. apart centre to centre transversely. The cross-girders are spaced 17 ft. apart centre to centre and rest upon the upper chords of the trusses and are cantilevered beyond the outer trusses. The three spans on the northern approaches are similar to those on the southern approaches, except that the approach is on a curve of 8 chains radius.

Tenderers are allowed the greatest latitude in the design of the bridge, which may result in economy in cost, and may submit proposals with that end in view. The cantilevers, girders of suspended span, cross-girders of the main bridge and girders of the approach spans may be constructed wholly of carbon steel, nickel steel, chrome nickel steel, or partly of any of them, as determined by the tenderers. The bridge may be built wholly of riveted members, or the tension members may be constructed of eye-bars and pins. The main piers, anchor piers, and piers and abutments of the approach spans, are to be constructed of concrete faced with granite masonry. The contractor has to satisfy himself as to the sufficiency and suitability of the design, plans and specifications and to undertake entire responsibility for the materials, construction, design, specifications, calculations, and plans furnished to or by him.

For the information of tenderers tables are given of the range of temperatures and intensities of prevailing winds, and the extreme velocities and pressures recorded during the severest storms in Sydney. A period of seven years is given for the completion of the work.

In view of the fact that a British Engineering Standards Committee has in hand a standard specification dealing with loading, &c., of bridges, we append extracts from the specification prepared by the chief engineer, Mr. John J. C. Bradfield, M.Inst.C.E.:—

Loads and Stresses to be Adopted in the Design of Bridge.

Dead Load.

In estimating the weight of the structure, for the purpose of computing the stresses therein, the unit weights at the top of the opposite page shall be used.

	Lb. per Cub. Ft.
Asphalt rock	150
Concrete, stone	150
Concrete, coke, including floating ...	84
Granite	170
Steel, rolled	490
Steel, cast	485
Wrought-iron...	480
Cast-iron	450
Timber, Ironbark or Grey Gum ...	75
	Lb. per Lin. Ft.
Rails and fastenings...	35
Guard rails and fastenings ...	32

The dead load shall consist of the entire weight of metal and other materials in the structure, computed in accordance with the above unit weights, with 2 per cent. addition to the calculated weight of steel for over-run.

LIVE LOAD.

All live loading or any combination thereof to be arranged to produce maxima stresses.

The deck system is to include the flooring plates, transverse rolled steel joists, stringers, the cross-girders and the ends of cross-girders cantilevered beyond the main trusses; also any sub-members and connections of the main system which may be more heavily stressed by the loading specified for the deck system than by the loading specified for the main system.

The main system is to include all members of the cantilevers, girders of suspended span, and girders of approach spans, other than those specified under deck system.

Deck System.—To be designed for the stresses produced by a uniform load of 100 lb. per square foot over the footway.

Main System.—To be designed for the stresses produced by a moving load of 450 lb. per lineal foot of bridge of such length as may be required to produce maxima stresses in the various members.

Deck System.—To be designed for the stresses produced by a uniform load of 100 lb. per square foot over the motor roadway, or for the concentrated loading of two motor 'buses side by side, heading in opposite directions. Wheel base, 15 ft. by 6 ft. Load on front axle 7,000 lb., back axle 12,000 lb., wheel bases 8 ft. centres. Space occupied by two 'buses side by side, 30 ft. by 18 ft. (See Figs. 5 and 6.)

Main System.—To be designed for the stresses produced by a moving load of 700 lb. per lineal foot of bridge, of such length as may be required to produce maxima stresses in the various members.

Deck System.—To be designed for the stresses produced by a conventional motor lorry (Figs. 7 and 8), wheel base 12 ft. by 6 ft.; overall length 24 ft., overall width 8 ft., space occupied 30 ft. by 12 ft. Weight, front axle 18,000 lb., back axle 36,000 lb. The remainder of the roadway to be covered with a live load of 100 lb. per square foot.

Main System. To be designed for the stresses produced by a moving load of 2,450 lb. per lineal foot of bridge, of such length as may be required to produce maxima stresses in various members.

Deck System. To be designed for the stresses produced by two coupled conventional electric locomotives, each 65 ft. long overall and weighing 160 tons, followed by a train 1,000 ft. long weighing 2,200 lb. per lineal foot on each of any two tracks of the four tracks, the remaining two tracks each carrying a train consisting of multiple unit stock, overall length of train 1,000 ft., weight 2,200 lb. per foot. (See Figs. 9 and 10.)

Main System. To be designed for 80 per cent. of the stresses produced by two coupled conventional electric locomotives, each 65 ft. long overall and weighing 160 tons, followed by a train 1,000 ft. long weighing 2,200 lb. per lineal foot on each of any two of the four tracks, the remaining two tracks each carrying a train consisting of multiple unit stock, overall length of train 1,000 ft., weight 2,200 lb. per foot. (Figs. 9 and 10.)

IMPACT.

Impact to be added to the statically computed maximum live load stresses produced by the electric railway loading as under:

	Per Cent.
Railway stringers	50
Floor beams and members of main system carrying one panel load or less ...	40
Members of main system carrying two panel loads and main girders of approach spans	25
All other members of main system ...	15
Deck plates, transverse steel joists and stringers	25
Floorbeams, cantilevered ends of floor-beams and members of main system carrying one panel load or less	20
Members of main system carrying two panel loads and main girders of approach spans	10
All other members of main system ...	5

No allowance to be added to stresses produced by the live load.

Impact shall not be added to the stresses produced by wind loads or by longitudinal and centrifugal forces.

WIND LOADING.

To be designed for the stresses produced by (*a*) A wind load normal to bridge of 30 lb. per square foot of the exposed surface of two trusses and one and a half times the elevation of the floor, 150 lb. per lineal foot of bridge on side walk fence (fixed load) and 30 lb. per square foot on travellers and falsework, &c., during erection. (*b*) A wind load parallel with the bridge load of 30 lb. per square foot acting on one half the area assumed for normal wind pressure in paragraph (*a*). (*c*) A wind load (moving load) of 300 lb. per lineal foot on the exposed surface of a train applied 7 ft. above base of rail.

TEMPERATURE.

To be designed for the stresses produced by (*a*) A variation of 120 deg. F. in the uniform temperature of the whole structure, normal temperature being taken as 60 deg. F. (*b*) A difference of 50 deg. F. between the temperature of steel and masonry. (*c*) A difference of 25 deg. F. between the temperature of a shaded chord and the average temperature of a chord exposed to the sun. (*d*) Stresses due to a difference of temperature of 25 deg. F. between the outer web exposed to the sun and the other webs of compression members.

Coefficient of expansion for steel for 1 deg. F = 0·0000061.

Fig. 5.

Fig. 6.

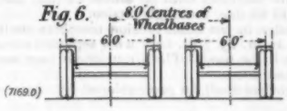


Fig. 7.

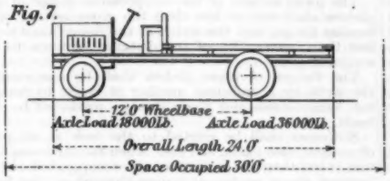


Fig. 8.

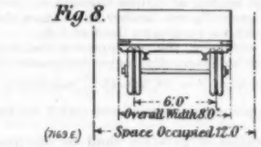


Fig. 9. MULTIPLE UNIT CAR AND TRAIN.

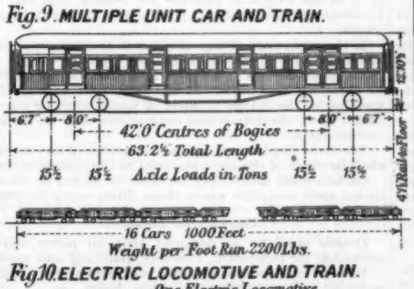
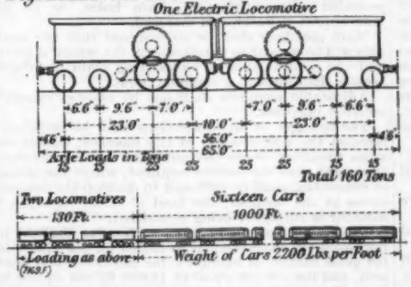


Fig. 10. ELECTRIC LOCOMOTIVE AND TRAIN.



TRACTION, BRAKE, FRICTION AND CENTRIFUGAL FORCES, &C.

To be computed for a total longitudinal force of 650 lb. per lineal foot for both tracks carrying traffic in the same direction.

To be computed for a brake force of 220,000 lb. for each truss assumed acting between suspended span and cantilever arm, the two end bays of lower chord of cantilever arm to be also computed for the additional forces arising from traction and longitudinal wind when the suspended span touches the stops limiting its longitudinal motion.

Torsion stresses in the suspended span from unsymmetrical loading shall be considered as primary stresses.

The tangential force produced by the rotation of a pin in its pinhole shall be assumed as 40 per cent. of the force on the pin. The force produced by the axial sliding of a pin in its pinhole as at the connection of the anchor arm with eyebars in masonry, and the connection of harbour arm and suspended span, shall be assumed to be 20 per cent. of the force on the pin.

The northern approach spans to be designed to provide for the centrifugal force due to a train on each of the two tracks in the same direction running at a speed of 25 m.p.h., the force to be applied 5 ft. above base of rails.

Provision to be made for the increased load carried by any member of the girders or deck due to the eccentricity of the load and to the effect of the centrifugal force.

In calculating the stresses of the anchor arm, the main pier is to be assumed both rigid and elastic, in which latter case the pier is to be assumed to resist torsion only. Modulus of torsion assumed at 1,200,000 lb. per square inch.

ERECTION LOADS.

The weight of the loaded travellers, erection plant and materials. If weights are estimated from drawings add 2 per cent. for overrun. On all weights based on information from suppliers of machinery and tackle, add 10 per cent. for possible overrun.

The heaviest load for each position of the travellers, &c.

Fifty per cent. of the load hanging from the upper blocks of main hoist.

A wind load of 30 lb. per square foot on the exposed surface of two trusses.

Considered not to co-exist.

LOADING USED TO DETERMINE THE SECTIONAL AREA OF MEMBERS.

All the co-existing loads and stresses and the deformation shall determine the section of the different members with the following restrictions:—

Temperature stresses (*d*) shall be considered as secondary stresses and temperature stresses due to (*c*) and (*d*) shall be assumed to co-exist with one quarter wind loads (*a*) and (*c*).

The various parts of the structure shall be proportioned for the maximum stresses produced by:—1. A combination of dead load, live load specified for railway tracks, main roadway, motor roadway and footway, impact, centrifugal force, if any, one quarter wind loads (*a*) and (*c*) and temperature stresses (*c*) and (*d*). 2. A combination of dead load, live load specified for railway tracks, one quarter live load specified for main and motor roadway, no load on footway, impact, temperature, longitudinal force and wind pressure as specified in Clauses (*a*) and (*c*). 3. Any combination of stresses due to co-existing wind loads, longitudinal force, centrifugal force, temperature, with dead load, live load impact and all secondary stresses.

UNIT STRESSES AND PROPORTIONING OF PARTS.

Any part of the structure built of carbon steel shall be proportioned so that the sum of the maximum stress produced by the loadings specified, including impact, shall not exceed the following amounts in pounds per square inch:—

Tension on net section	Lb. per Sq. In.
Eyebars	20,000
Riveted members	18,000
Including secondary stresses ...	24,000
Compression on gross section	
Members with l/r under 50 ...	14,000
Members with l/r 50 and over 50	18,000–80 l/r
Including secondary stresses ...	18,000
Bearing on	
Shop rivets...	22,000
Field rivets	20,000
Rollers per lineal inch, where d = Diameter of roller in inches ...	600 d.
Pins in eyebars	22,000
Pins in riveted members	20,000
Bending on extreme fibres of	
Pins	25,000
Steel castings	16,000
Shearing on	
Shop rivets and pins	11,000
Field rivets	10,000
Webs of plate girders, gross section	10,000
Steel castings	11,000

If nickel steel or chrome nickel steel is used, the unit stresses given above for carbon steel may be increased by 40 per cent., except in the tensile unit stresses which may be increased by 45 per cent.

From Live and Dead Loads, Wind, Traction, &c.—	Lb. per Sq. In.
Granite	800
Concrete, 1–1¼–4	500
Concrete, 1–2–5	450
Foundations	Lb. per Sq. Ft.
Solid sandstone, dead and live loads	40,000
Solid sandstone, dead and live loads, including wind and traction, &c.	70,000
Hard shale	20,000

All parts of the steel structure shall be proportioned so that the sum of the maximum stresses during erection

shall not exceed the unit stresses specified for the members of the bridge when erected, by more than 20 per cent. Erection unit stresses are to be used for all conditions of loading when designing the top chord eyebar supporting trusses, if eyebars are used.

For rivets with a grip greater than four diameters, reduce the units specified by 1 per cent. for each $\frac{1}{16}$ in. of additional grip, except in compression members having butt joints, but no rivet shall have a grip exceeding $7\frac{1}{2}$ diameters.

Take both systems in calculation of strains, disregarding reversal of strains.

For compression ... ... $16{,}000 - 70\ l/r$

In calculating the laterals and cross-bracing, the axial deformation stresses arising from the lengthening and shortening of the truss members by the dead and live load stress shall be considered.

In calculating the number of rivets in the connections of laterals and cross-bracing, these axial deformation stresses shall be neglected.

Anchor piers shall have a factor of safety of two for all primary stresses including impact.

The stresses in statically indeterminate structures shall be calculated from their elastic deformations, and all assumptions made and formulæ used for the calculations must be given in stress sheets to be submitted.

All bending stresses in compression members produced by the weight of the member itself and by loads, applied on the member shall be considered as primary stresses.

All such members shall be proportioned so that the greatest fibre stress due to this bending and axial strain together will not exceed the allowed units for the axial stress in that member.

No bending stresses from weights of members shall be considered in eyebars and built tension members.

For laterals in cantilever and anchor arm, assume members fixed at both ends. For sway bracing in cantilever and anchor arms, assume members hinged at both ends for bending normal to the plane of the bracing, and fixed at both ends for bending in the plane of the bracing.

All stresses produced owing to the deformation of the steel work under any and all loads, either by the absence of pins at the joints or by the friction on pins opposing the turning of members, shall be considered as secondary stresses.

Secondary stresses due to impact to be considered.

Secondary stresses due to temperature as specified in Clause (*b*) and (*c*) not to be considered.

Truss members subject to alternate tension and compression shall be proportioned either for—(*a*) The net area obtained by dividing the tension stress by the unit tensile stress; or (*b*) The net area obtained by dividing the tension stress by the unit tensile stress added to the gross area obtained by dividing the compression stress by the unit compressive stress, the unit compressive stress before dividing to be reduced by the bending stress due to the weight of member.

If in a member subject to alternate stress, $\frac{D}{T}$ is greater than 24 or 30 respectively, the area remaining after reduction on this account must be adequate for the compression and bending, and the total area must be adequate for all stresses, where D is the unsupported distance between rivet lines and T is thickness of plate.

Rivets in truss members, laterals and bracing are to be proportioned for the sum of the positive and negative stresses.

Laterals and cross-bracing shall be proportioned for the sum of the primary compression stresses in addition to the bending stresses from weight of member, and also for the sum of primary tension stresses. The larger of the two sections so determined shall be chosen. Their connections shall be designed for the sum of the primary tension stresses plus the sum of the primary compression stresses neglecting the bending stresses due to weight of member.

In designing end members and details which may be subject to alternate stresses, and laterals at the ends of the cantilever and anchor arms, the effect of traction temperature (*c*), brake and friction stresses shall be taken into account together with stresses arising from dead and live load, impact and wind. The required area shall be the area obtained by dividing the sum of the stresses producing compression by the unit compressive stress minus the bending stress due to weight of member, added to the area obtained by dividing the sum of the brake and friction stresses by the unit tensile stress.

In calculating the net area of tension members, the rivet holes shall be taken $\frac{1}{8}$ in. larger than the nominal diameter of rivets before driving.

In proportioning rivets, the diameter of the rivet before driving shall be used.

Tension members shall be given full splice in material and rivets.

All splices in compression members shall be given full strength in material and a sufficient number of rivets for the axial stress. Full area and rivets for secondary stress shall also be provided

Pin-connected riveted tension members shall have a net section through the end pinhole at least 33 per cent. in excess of the net section of the body of the member, and the net section back of the pinhole parallel with the axis of the member shall not be less than 80 per cent. of the net section of the body of the member. The net section through the intermediate pin holes shall be increased over that of the member by the section cut out by the pinhole.

In no case shall the width of the built tension members be more than 15 times the thickness at the pin unless provision is made to stiffen the member behind the pin The ends of built tension members shall be square whenever possible.

The latticing of compression members to be proportioned for a cross shear per square inch of gross section of 2 per cent. of the unit stress for short strus of the same material; if the weight of the member produces additional shear this must also be provided for.

The compression unit stress in carbon steel for bars in single lacing shall be $8{,}600 - 63\frac{L}{T}$, and in double-lacing $8{,}600 - 42\frac{L}{T}$, where L = length, T = thickness. For nickel steel and chrome nickel steel increase the unit stresses by 40 per cent.

The unit stress in angle lacing shall not be more than 18,000 lb. per square inch on net section of connected leg or more than 14,000 lb. per square inch on gross section of connected leg.

Double lacing shall be used for all main members of trusses. Single lacing may be used for laterals, sway bracing, and secondary members. For double lacing with rivets at intersection of bars, the length nearest end rivets shall in truss members and laterals be not more than 60 times, and in sway bracing not more than 80 times the thickness of the bar.

For single lacing in laterals and secondary truss members the length between nearest rivets shall not be more than 40 times and in sway bracing not more than 50 times the thickness of the bars; l/r for angles shall not be greater than 100 for double lacing, or greater than 67 for single lacing.

The inclination of the lattice bars and angles with the axes of the members shall be about 45 deg. for double lattice, and 60 deg. for single lattice.

The lattice in the main tension members shall be not less than $4\frac{1}{2}$ in. by $\frac{3}{8}$ in. bars with separate rivets. No fillers are to be used. The l/r in these bars not to be greater than 80.

Plate girders shall be proportioned by their moment of inertia.

The gross section of the compression flange of plate girders shall not be less than the gross section of the tension flange, and the width of the flange shall not be less than one-twelfth of the distance between its side supports.

The flanges of plate girders shall be connected to the webs by a sufficient number of rivets to transmit the flange stress and those stresses produced by local loads.

Stiffeners shall be riveted to the web at all points of concentrated loads, and also, when the thickness of the web is less than one-sixtieth of the unsupported distance between flange angles, at points throughout the length of the girder, generally not further apart than the depth of web plate, with a maximum limit of 6 ft.

In spacing stiffeners, the unsupported distance, D in inches, between stiffeners shall never be greater than the value obtained from $S = 13{,}500 - 45\frac{D}{T}$, where S is the web shear stress in pounds per square inch and T the thickness of the web.

Minimum radius of gyration shall be one-hundredth ($\frac{1}{100}$) of the length of member for trusses, and one, one hundred and twentieth ($\frac{1}{120}$) for lateral and sway bracing struts.

If the main part of any member of the trusses is made of nickel steel or chrome nickel steel, all the details and connections of such members shall also be nickel steel or chrome nickel steel. If the main part of any other member of the bridge is made of nickel steel or chrome nickel steel, the details and connections may be made of carbon steel.

The cross diaphragms normal to the axis of any member shall be made of the same material as the main section.

Carbon steel fillers may be used in nickel or chrome nickel steel members where these fillers carry no stress.

Details of Design.

Details shall be so designed that all parts will be accessible for inspection, cleaning, painting and repairs.

Pockets or depressions which will hold water shall be provided with satisfactory drain holes, or be filled with approved waterproof material.

Main members shall be so designed that the neutral axis will be as near as practicable in the centre of section, and the neutral axes of intersecting main members of trusses shall meet at a common point.

Adjustable members shall not be allowed except for erection purposes.

The strength of all connections shall be sufficient to develop the full strength of the member, except main truss members where the minimum section obtainable is greater than the section required, where the strength of connection shall be sufficient to develop the computed stress in the member, the kind of stress to which the member is subjected being considered.

The rivet connections for sway bracing shall be proportioned for a stress equal to 12,000 lb. per square inch for gross section of members, for cantilever and anchor arm, and for a stress equal to 14,000 lb. per square inch for gross section of member for suspended and approach spans whenever the specification calls for fewer rivets.

Bottom Lateral, Gusset Plate, Cantilever Arm and Anchor Arm.—A width of plate not greater than 30 times the thickness between the lines of rivets connecting them to flanges, plus 15 times the thickness outside the line of rivets on either side of member, shall be used in determining the thickness of plates required to develop the section, unless the bending moments on the plates require a greater thickness. In no case shall the plates be less than $\frac{1}{2}$ in. thick.

Web Plate Splices.—In truss members where web plates only are spliced and where no side plates are used, the splice material must cover the flange angles on both sides of the web. In members where plates only are spliced and where side plates are used, the splice plates need not cover the angles, but sufficient moment of inertia must be provided in splice plates, and the length of the splice plate between the angles must be at least $1\frac{1}{2}$ times the distance between the angles.

Gusset Plates.—Gusset plates shall be examined by means of sections either curved or straight; and the assumed net section shall be able to take care of the axial stress and induced bending stress, due to eccentricity of applied force, at a unit stress not exceeding 18,000 lb. per square inch without secondary, and 21,600 lb. per square inch including secondary, for carbon steel.

No steel in deck system except fillers, handrailing and web cover plates of stringers may be less than $\frac{1}{16}$ in. thick; the buckled plates for deck of footway and motor roadway, also the web plates of stringers for main and motor roadways and footway may be $\frac{1}{16}$ in. thick. Any other material in deck system, also material for the floor bracing, lacings for sway and lateral bracing for the top chord, supporting trusses and for the lacing of the main tension members, may be not less than $\frac{1}{8}$ in. thick. All other material used to be not less than $\frac{1}{4}$ in. thick.

The nominal diameter of rivets shall be at least :—

$\frac{7}{8}$ in. up to $3\frac{1}{4}$ in. grip.
1 in. from $3\frac{1}{4}$ in. to $5\frac{1}{4}$ in. grip.
$1\frac{1}{4}$ in. from $5\frac{1}{4}$ in. grip and over.

The diameter of rivet holes shall be $\frac{1}{16}$ in. larger than the diameter of rivet.

The actual diameter of rivets will be such as to require when heated, a slight pressure to force them into the hole. The size of rivets shall be adjusted to fill this condition.

The minimum distance between centres of rivets shall be three diameters of the rivet holes. The maximum pitch in the angles in the line of strain for members composed of plates and shapes shall be five diameters of the rivet holes. For angles with two gauge lines, the maximum shall be twice the above in each line with rivets staggered.

The maximum distance between stitching rivets on the edges of tension members shall be 10 times the minimum thickness of any one of the plates connected.

The maximum distance between stitching rivets in compression members shall, with one longitudinal line of rivets, not exceed 12 times the thickness of the thinnest plate. With more longitudinal lines of rivets the distance in each of these lines shall not exceed 16 times the thickness of the thinnest plate, provided the distance of each rivet from each of two rivets of an adjacent line is not more than 12 times the thickness of the thinnest plate. In no case shall the distance from any one to the nearest rivet exceed 12 in.

The minimum distance from the centre of any rivet to a rolled or planed edge shall be $1\frac{1}{4}$ times the diameter of the rivet hole for hand-driven rivets, and $1\frac{3}{4}$ times the diameter of the rivet hole for machine-driven rivets.

The maximum distance from any edge shall be eight times the minimum thickness of any one of the pieces connected, but shall not exceed 6 in.

The pitch at the ends of built compression members shall not exceed four diameters of the rivet holes for a length equal to $1\frac{1}{2}$ times the depth of the member.

If riveted to truss members the holes in floor beams for the rivets connecting them to the truss members shall be drilled in such a manner that, after riveting, the end moment in floorbeams is zero under dead plus half-live load on railway and main roadway.

The thickness of plates in compression members shall not be less than one twenty-fourth of the distance between the lines of rivets connecting them to the flanges for webs of main truss members, and one thirtieth for coverplates and horizontal diaphragms, and one fortieth for the cover plates of the top chord supporting trusses, if any.

The open sides of compression members shall be provided with lattice and shall have tie plates as near each end as practicable. Tie plates shall be provided at intermediate points where the lattice is interrupted. In main members carrying calculated stress, the end tie plate shall have a length not less than the distance between the lines of rivets connecting them to the flanges, and intermediate ones not less than half the distance. Unless stiffened by angles they shall have a thickness of at least one-fiftieth the distance between rivet lines.

Tie plates shall be $\frac{1}{2}$ in. thick in laterals, $\frac{3}{8}$ in. thick in bracing, and they shall be stiffened by angles of the same section as the lacing, when D/T is more than 60 (where D = distance of rivet lines connecting them to the main section and T = thickness of plate), unless thicker plates would be more economical.

The tie plates of the bottom laterals shall be at least as long as broad; those of the sway bracing at least two-thirds as long as broad. When they are stiffened by angles, these should be at intervals of about the depth of the member.

The net section of any tension flange or member shall be determined by a plane cutting the member square across at any point. The greatest number of rivets which can be cut by the plane or that come closer than the dimensions following are to be deducted from the gross section of the member.

Dimensions.	Rivets, Diameter.
In.	In.
$1\frac{1}{2}$	$\frac{3}{4}$
2	$\frac{7}{8}$
$2\frac{1}{2}$	1
3	$1\frac{1}{4}$

Abutting joints in compression members shall be faced.

Pin holes shall be reinforced by plates where necessary, and at least one plate shall be as wide as the flanges will allow, so that the allowed pressures on the pins shall not be exceeded, and so that the stresses shall be properly distributed over the full cross-section of the member. These reinforcing plates must contain enough rivets in front of two lines through the centre of pin, each

under 45 deg. with axis of member, to transfer their proportion of the bearing pressure. They shall be at least as long from centre of pin to end as the width of the member.

When forked ends are used they shall be made at least twice the sectional area of the member, and at least as strong as the body of the member.

Pins shall be long enough to ensure a full bearing of all parts connected upon the turned body of pin. They shall be secured by approved nuts and be provided with washers if solid nuts are used. The screw ends shall be long enough to admit of burring the ends.

Members packed on pins shall be held against lateral movement. Filling rings shall be of bent steel plate.

Provision shall be made for the expansion produced by a variation of temperature of 120 deg. F. Coefficient of expansion = 0·0000061.

Lateral, longitudinal and transverse bracing in all structures shall be composed of rigid members.

Transverse frames rigidly connected to posts and chords shall be used at each main post and at the ends of the through portion of the bridge. They shall be as deep as the clearance will allow. Other transverse frames shall be used at all points where needed.

Where flange plates are used, one cover plate of top flange shall extend the whole length of girder.

Web stiffeners shall be in pairs. Those over the end bearings shall be on fillers. The outstanding legs shall be as wide as the flange angles will allow, and they shall be brought to a close bearing against the upper and lower flange angles. Intermediate stiffeners shall be crimped over the flange angles. Their outstanding legs shall be not less than one thirtieth of the depth of the girder plus 2 in. The thickness of all stiffeners shall not be less than $\frac{3}{8}$ in. and the rivet pitch in them shall not be over 5 in.

The lengths of all main truss members shall be such that, with the channel span fully loaded and the shore arms unloaded, all main panel points shall be in their geometrical positions. Deformations from impact stresses shall be neglected. A modulus of elasticity of 29,000,000 lb. per square inch shall be assumed. Proper allowance to be made for details on the compression members.

Open joints during erection will not be allowed in any part of the trusses.

The eyebars composing a member shall be parallel to the axis of the truss. In case this is found impossible, approval to use a maximum inclination for any bar not exceeding 1 in. in 16 ft. must be given by the chief engineer.

All false work shall rest on concrete pedestals built on shale or rock foundations, or if allowed by the engineer, set at least 5 ft. deep into the ground.

The contractor shall provide and erect between the suspended span and the cantilever arms, effective brakes to prevent motion of the suspended span under traction forces.

BOILER EXPLOSION: NO SAFETY VALVE.

THE Board of Trade, under the provisions of the Boiler Explosions Acts, 1882 and 1890, have made a preliminary inquiry as to the circumstances and cause of an explosion which occurred on January 17, 1921, at the works of the Ouse Shipbuilding Company, Limited, Hook, near Goole, but by which, fortunately, no person was injured. The following particulars are taken from the report sent by the surveyor, Mr. P. J. Thompson, of Hull, who made the examination, to the Assistant Secretary of the Mercantile Marine Department, Board of Trade :—

The boiler was of the vertical type and was used for driving a 5-ton crane. The shell was 7 ft. 6 in. in height, 3 ft. 6 in. mean diameter, and was constructed of two courses of plate $\frac{3}{8}$ in. in thickness. The vertical seams were lapped and double riveted ; the pitch of the rivets was $2\frac{3}{4}$ in. centre to centre, and the diameter of rivets was $\frac{13}{16}$ in. ; the distance between the rows was $1\frac{3}{4}$ in. and the distance from centre of rivets to edge of plates was $1\frac{1}{4}$ in. The circumferential seams were lapped and single riveted. The crown was $\frac{3}{8}$ in. thick and was flanged and attached to the upper course of shell plating, and to the uptake, by single riveting.

The fire-box was 4 ft. 2 in. in height, 2 ft. 11 in. mean inside diameter, $\frac{7}{16}$ in. in thickness, with a vertical seam. It was flanged at its base for connection to the shell, and fitted with two welded cross tubes of 8 in. external diameter. The crown of the fire-box was $\frac{13}{32}$ in. in thickness. It was flanged and connected to the fire-box and to the uptake by single riveting. Between the fire-box crown and the crown of the shell was a plain uptake tube 10 in. in external diameter and $\frac{3}{8}$ in. thick. The vertical seam of the fire-box was lapped and single riveted, and the riveting in the crown plate to fire-box and in the fire-box connection to the shell plate was the same as that in the vertical seam of the fire-box.

The mountings included one steam stop valve, one pressure gauge, one water gauge, one feed check valve, one blow-down cock, and one fusible plug in fire-box crown.

The crane to which the boiler was fitted was one of a number built under a War Office contract with Messrs. Butters Brothers and Co., Limited, Glasgow, who had a number of similar boilers built by several makers, and it is therefore difficult to state definitely the name of the boiler makers. According to Messrs. Butters Brothers, who also fitted the boiler mountings, the crane with the boiler was completed in 1917.

No repairs were done to the boiler after delivery at Hook, and none appeared to have been effected at any previous date. The shell and fire-box of the boiler were inspected on November 17, 1920, by Mr. J. R. Bromfield, who represented the Automobile, Aircraft and Engineering Insurance Company, Limited. The boiler was insured at the time of the explosion with the company named, at their office in Aldwych, W.C., but it was a condition of the insurance that the boiler was to be efficiently mounted before being put to work.

The explosion was of a violent nature, the fire-box collapsing and the boiler crown plate, at the radius of the flange for taking the uptake, being completely sheared. The uptake, due to the collapse of the furnace and the shearing of the crown, was forced 11 in. downwards into the boiler. The shell plate about the fire-box door was bulged owing to the collapse of the furnace, and some of the rivets were started. The stop valve and steampipe were broken from the boiler and appeared to have been blown into the adjacent river. The cover over the boiler was blown aboard a ship lying about 50 ft. away at the jetty. The ends of the fire-box cross tubes gave out and the fire bars were either blown out or broken.

The explosion was due to excessive pressure.

Mr. Thompson gives further information in his general remarks, as follows :—

"The boiler had been in use by the Ouse Shipbuilding Company for about eight working days prior to this explosion, and had been purchased with its mountings at an Army sale. I inspected the boiler on January 18, 1921, found it inclined at an angle of about 15 deg. to the vertical, with fire-box sides and top collapsed, and the boiler crown at the radius of flanging to uptake sheared. At the aperture for the safety valve nothing remained but a flange ; the valve was stated to have been blown into the river.

"The shell and fire-box had been inspected by Mr. Bromfield, who reported to his company, and a working pressure of 80 lbs. per square inch had been allowed. The mountings, including the safety valve, were not inspected by Mr. Bromfield. He states that he had asked the secretary of the Ouse Shipbuilding Company to notify him when the mountings were fitted, for the purpose of inspection and floating the safety valve. He was not, however, informed, and no certificate was issued, but the boiler was entered on the insurance policy with other boilers, and would be covered by this policy subject to the necessary mountings being fitted.

"After the explosion," Mr. Thompson goes on to say, "I examined the shell and fire-box, and had all plates drilled. The workmanship generally was good, and the boiler was suitable for a working pressure of 80 lb. per square inch. From the condition of the plating the boiler appeared quite new and to have been used very little, if at all, prior to purchase by the Ouse Shipbuilding Company. I examined the water gauge cocks and other fittings and found them in satisfactory condition. The fusible plug showed no signs that there had been shortness of water.

"Mr. Jordan, the foreman fitter, stated in evidence on January 31, 1921, that he fitted the mountings, including the safety valve, but was 'in no position to say what type of safety valve was fitted' ; also 'the safety valve had not been floated and had never been tried by me or any one else. The safety valve appeared new when taken out of the box, and did not appear to have been used ; and that he 'had never heard or seen the safety valve lift or blow.' The fireman and the watchman stated that they 'had never heard the safety valve blow.' The safety valve could not be produced after the explosion, and Mr. Hambling, general manager, thought that it was 'probably under water and in the mud,' and had it 'searched for without any success.'

"Considerable delay was caused while search was being made for the valve. Attempts were made by correspondence to trace the makers of the boiler and of the alleged safety valve. This latter correspondence increased the delay and, as it afterwards appeared, was unnecessary.

"Evidence was again taken from Mr. Jordan on April 18, 1921, from which it transpired that no safety valve had been fitted. In his amended evidence he states : 'When we opened the case containing boiler fittings we took all the gear out of it ; all the small fittings were at the bottom of the case, and after emptying the case completely we could not find the safety valve.' He reported the matter, but as some 'urgent lifts were required for a boat at the jetty, he was asked by one of the managers (stated by Mr. Hambling to have been Mr. Campbell, yard manager) if the boiler could be used without a safety valve. He said he could fit a stop valve in the place of the safety valve as a temporary measure, to get the firm over the difficulty. A screw-down stop valve was accordingly fitted to the boiler crown plate over the aperture intended for the safety valve, the crane being worked by steam from the valve.' The full facts of the case only came to light when this report was being drawn up.

"The boiler was worked under the above conditions for about eight working days prior to the explosion, and Mr. Jordan states that he never saw the steam above 55 lbs. per square inch, and that he 'continually kept the pressure gauge under observation to prevent the pressure rising.' This appears to have been done by the use of the dampers, feeding up with water, and by running the crane engine light if necessary, there being no other means of releasing any accumulation of steam. During the eight working days the crane was in use steam was raised during the day when required, and the fire was allowed to go out at night. On Sunday, January 16, the fireman cleaned out the fire and prepared for lighting with wood and coal. He tried the water gauge and observed that the water level was about two-thirds glass. The night watchman was asked to light the fire at 6.15 a.m. the following day, January 17, with the intention of being ready for the crane man who was due to arrive at 7 a.m. Instead of lighting the fire at 6.15 a.m. he lit it at 4.45 a.m. During the morning a very strong breeze was blowing from the River Ouse direct towards the boiler ashpit, and consequently the fire would burn very fiercely, the boiler being on an exposed jetty. At about 6 a.m. a loud report was heard, due to the explosion of the boiler. No one appears to have been near at the time. The night watchman did not approach the boiler after setting the fire alight, and therefore no one observed the pressure gauge, but as no safety valve was fitted it is, in the circumstances, reasonable to suppose that a considerable pressure was present in the boiler, which, being largely in excess of that for which it was intended, brought about the explosion in the manner described."

Mr. Thomas Carlton, Chief Engineer Surveyor to the Board of Trade, gives the following "Observations" on the above report presented by the Assistant Surveyor, Mr. Thompson :—

"It is evident," he says, "that in the course of this preliminary inquiry, persistent attempts were made by certain individuals concerned to mislead the surveyor on the question of the safety valve fitted to the boiler, but it finally emerged from the evidence that no safety valve had been supplied with the mountings, and that the boiler was without one when the explosion occurred, and for eight days prior to the explosion the boiler had been worked thus imperfectly equipped.

"But for the incidents disclosed in this report, it would be almost inconceivable that any person making the slightest claim to engineering knowledge could be so reckless of the lives and safety of his fellow-workmen as to raise steam on a boiler upon which there was no safety valve, and it is the more extraordinary that in this case such risk should have been undertaken with the full knowledge and consent of a responsible shipyard manager."

Mr. Carlton concludes by saying : "The seriousness of the risks taken is sufficiently apparent from the violent nature of the explosion, and it must be a matter of congratulation among those connected with this deplorable case that nobody was in the immediate vicinity of the boiler when it failed."

To any reader of this report the reference by Mr. Carlton to what he rightly terms "this deplorable case" will at once appear to be well merited. The extreme laxity prevailing in the fitting-up and setting to work of this boiler by those concerned would seem to be beyond belief with all the knowledge and experience so readily at hand. The chief actors in this "happy go lucky" venture may also congratulate themselves that they have not had to submit to a formal investigation by the Board of Trade under the Boiler Explosions Acts, together with the levy of a substantial pecuniary penalty which would probably have resulted and which would have been richly deserved. The further question arises as to what part the regulations of the Factory Act with regard to the inspection and working of a boiler have played in this case since the careful examination and certification of boilers was introduced to prevent explosions due to such ignorance and carelessness as has been exhibited on this occasion. What became of the Factory Act Report and the necessary certificate for permitting work if they existed, and, if they did not exist, what was the reason ? The Act is regularly enforced where the greatest skill and care are already exercised, and it would appear to be unfortunate if it should fail and not be applied just when its presence and practical activity, if rightly carried out, would doubtless have prevented this explosion.

THE ROYAL SANITARY INSTITUTE.—Major-General the Right Hon. J. E. B. Seely, C.B., C.M.G., P.C., D.S.O., M.P., has consented to accept the office of President of the Thirty-Third Congress of the Royal Sanitary Institute, to be held at Bournemouth from July 24 to 29, 1922.

CRYSTAL PALACE SCHOOL OF PRACTICAL ENGINEERING, ENGINEERING SOCIETY.—The Wilson premium for the best paper read before this society during the past session, has been awarded to Mr. B. W. Rowe for his paper on "Road Construction." A number of other papers were read and discussed during the session.

TRADE WITH INDIA.—Mr. E. W. Petter, chairman of the British Engineers' Association and a member of the Executive Committee of the Industrial League and Council is going to India on business for his firm. Mr. Petter is the managing director of Messrs. Vickers-Petters, the well-known oil engine experts and manufacturers. The excellent relations prevailing between the directorate and the employees was manifested at Ipswich last week, when a supper and concert was organised to give Mr. Petter a cordial send off. Over 300 employees of the firm attended the function. One of the objects of the Industrial League is to promote foreign trade, and Mr. Petter in his visit to India will receive all the co-operation which the League can accord him.

SOCIETY OF ENGINEERS.—The annual general meeting was held on the 12th inst., when the following premiums for papers read during 1921 were awarded : President's gold medal to Mr. G. O. Case, for his paper on "The Winning of Tidal Lands in British Guiana" ; Bessemer premium to Mr. R. W. A. Brewer, for his paper "Some Modern Engineering Practice in America" ; Nursey premium to Mr. Alfred S. E. Acherman, for his paper on "The Physical Properties of Clay" (third paper) ; Society's premium to Mr. W. M. Beckett, for his paper on "Northwick Sewerage and Sewage Disposal Works" ; Green premium to Mr. C. F. Moore, of the Crystal Palace Engineering Society, for his paper on "The Locomotives of the London and North-Western Railway." (The meetings are open to members of associated societies.)

THE QUIMBY SCREW PUMP.

CONSTRUCTED BY MESSRS. W. QUIMBY (INCORPORATED), ENGINEERS, NEWARK, NEW JERSEY, U.S.A.

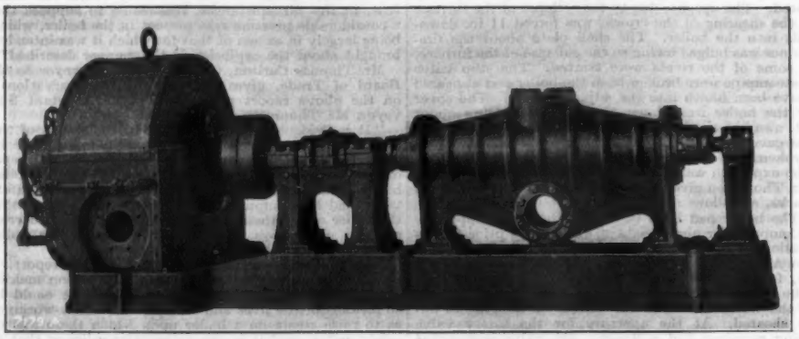


Fig. 1.

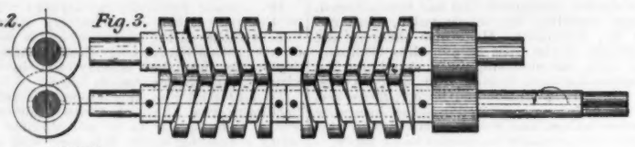


Fig. 2. Fig. 3.

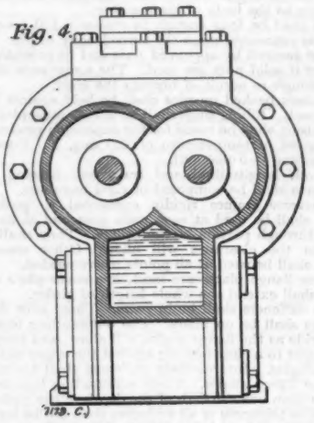


Fig. 4.

We reproduce from the Journal of the American Society of Naval Engineers illustrations (Figs. 1, 2 and 4) of a highly ingenious form of rotary pump, which is, it appears, capable of working very satisfactorily against very high heads. The pump is made by Messrs. Wm. Quimby (Incorporated), of 209, Parkhurst-street, Newark, N.J., and has been adopted on certain American warships for pumping oil fuel. Its general appearance is well represented in Fig. 1, whilst the principle on which it works will be readily understood on reference to Fig. 2. The essential feature of the pump consists of opposing pairs of intermeshed right and left-handed screws. The two shafts are geared together as indicated. The space at the outer ends of the screws are coupled up to the oil supply, and the oil is forced towards the centre as the screws rotate. A cross-section through the pump is represented on Fig. 4, from which will be seen that the screws fit the casing closely. The pump illustrated has a 2-in. suction branch, and a 1½-in. discharge orifice. It is driven electrically, and in certain tests made with it at the Fuel Oil Testing Plant Navy Yard, Philadelphia, was coupled to a 15-h.p. variable speed motor, which was run at speeds ranging from 740 to 1,210 r.p.m. The discharge pressure was varied from 100 to 450 lb. per square inch. With a delivery pressure of 100 lb. per square inch, the maximum discharge was 46¼ gallons (U.S.A.) per minute; and at 450 lb. per square inch a discharge of 15¾ gallons per minute was maintained.

In some additional experiments a pressure of 540 lb. per square inch was attained. Used as a suction pump, a vacuum of 26 in. was maintained at the pump inlet.

At the lower pressure an efficiency of over 60 per cent. was reached, and with a pressure of 450 lb. per square inch it ranged from about 25 per cent. up to 37 per cent. The pump, it should be added, had been in service for three and a-half years before the tests were made. During this time it is stated to have required no repairs save an occasional renewal of the packing in the shaft stuffing boxes, and an examination at the end of the term mentioned showed no perceptible wear. The pump is stated to run without noise, other than that due to the gear wheels.

THE TRADE OF INDIA.

A general review of British trade in India during the fiscal years 1919–20 and 1920–21, by Mr. T. M. Ainscough, H.M. Service Trade Commissioner in India and Ceylon, has recently been issued by the Department of Overseas Trade. It covers the whole activities of the Empire. Taking the products which will appeal to most of our readers, and dealing with the year 1919, we find the following total values for some of the mineral productions of India: Coal, 10,119,256*l.*; gold, 2,256,039*l.*; petroleum, 1,834,308*l.*; salt, 1,823,522*l.*; manganese, 1,546,330*l.*; mica, 863,448*l.*, followed by many others in the list, including copper ore, 52,416*l.*; iron ore, 45,887*l.*; magnesite, 19,728*l.* In the matter of coal, the present position is reported to be extremely serious, since, owing to a variety of reasons, including reduced output by the miners and shortage of wagons, the raising of coal was considerably reduced in 1920, the present supplies being short of the requirements of the country. Steps have been taken to curtail the exports of coal from India, and proposals are now being considered for the creation of an organisation for the conservation of the coal supplies and the prevention of waste. The petroleum production, the value of which is given above, amounted to 305,651,816 gallons. Notwithstanding this output, the imports of mineral oil aggregated in 1918–19 over 60,000,000 gallons, and in 1919–20 over 144,000,000 gallons, the total quantities shipped being 532,479 cwt., valued at 1,216,252*l.*, and the principal destinations being the United Kingdom, Japan and Australia. The total output of iron ore, valued at 45,887*l.*, was 563,750 tons. The Tata Iron and Steel Company, Limited, produced 232,638 tons of pig-iron, 134,061 tons of steel, including rails, and 2,650 tons of ferro manganese. The production of the Bengal Iron and Steel Company was 84,965 tons of pig-iron, 4,732 tons of ferro manganese and 29,635 tons of iron castings. The output of manganese ore amounted to 538,000 tons, and of this, 370,000 tons, valued at 697,732*l.*, was exported, mainly to the United Kingdom.

In regard to hydro-electric power supply, the present position is the following. The original Khopoli scheme for the supply of power from the Western Ghats to the Bombay mills has been working satisfactorily for some years. The Andhra Valley scheme to supplement the former supply is almost completed, and it is expected that power will be supplied early next year. The Nilamulla scheme for a third power station in the Western Ghats to supply Bombay is now in progress. Owing to the present abnormal conditions, the placing of contracts for machinery and plant may be deferred for a little time. The great Koyna River project has been carefully examined, and a great deal of preliminary work done, but the scheme is so vast and will entail such a great expenditure of capital, that it will probably have to be postponed until large issues can again be made in the Bombay money market. In the meantime the Hydro-Electric Survey of India has proceeded steadily with its work on the water power resources of the country.

The report further reviews the forest economy, agriculture, irrigation, the jute, tea, cotton and other trades and industries, railways and shipping, and states that motor transport is rapidly extending in the principal trade centres, motor lorries gradually superseding the bullock cart in the transport of goods between docks and warehouses in Calcutta and Bombay. A transport company is now running a goods service between Calcutta and the colliery district. The postal authorities are also employing motor vans and lorries for city delivery and for the heavy hauls up the various hill stations in Kashmir and other parts where railway facilities do not exist. There is little doubt, the report adds, that within the next few years there will be a great advance made in motor conveyance of passengers and goods; the present deterioration in the railway services and shortage of coal may tend to expedite this. Civil aviation is also receiving the attention of the Government of India.

THREE-WHEEL WATER-BALLAST MOTOR ROAD ROLLER.

The name of Messrs. Barford and Perkins, Limited, of Peterborough, is so well known in connection with motor road rollers that much interest will be taken in the new model which they have produced and which is illustrated in Fig. 1, on page 885. This new model has been designed to meet the demand for a motor road roller with the customary wheel arrangement of a steam roller. The nominal weight is 10 tons to 13 tons, and by placing the engine at the rear it has been possible to obtain a wheel base of only 9 ft. 9¾ in., which is claimed to be considerably less than that of any other three-wheel roller on the market. The short wheel base in conjunction with the differential gear enables the roller to turn completely round within a circle of 31½ ft. diameter. Both the back and the front rollers are arranged for water ballast, the two back rollers together accommodating 1 ton and the front roller taking 17½ cwt. In addition there is a sprinkling water tank of 120 gallons capacity, which can be used as a water ballast tank and adds an additional 10½ cwt. This gives a total variable weight of 2 tons 8 cwt.

The roller follows motor lorry practice as far as possible, particularly in the arrangement of the engine, radiator, starting handle and bonnet. This will be sufficiently clear from the general view of the engine given in Fig. 1 and the side view of the roller given in Fig. 2. This last figure clearly illustrates the carrying of the engine behind the back axle, which makes the short wheel base possible. The controls are those usual on commercial motor vehicles and comprise clutch pedal, foot-brake pedal, central change gear levers with selector gear and throttle and ignition controls. All motions necessary for the driving of the roller are under control of the driver without leaving his seat, including the water supply to the sprinkling pipes on the front and rear rollers. The arrangement of the starting handle is shown in Fig. 4, which illustrates both the slip clutch and the way in which the handle is made to fold inwards when not in use, to protect it from accidental damage, and also to reduce the overall length of the roller.

The position of the engine at the rear of the machine makes it very accessible, and it can easily be removed entirely without interfering with the transmission. The engine itself, together with the whole of the transmission and a portion of the steering gear are mounted on a sub-frame which is bolted to the main frame carrying the rollers and tanks. This sub-frame can be dropped and slipped out at the rear end when any extensive overhaul, or repair, is required. The arrangement also facilitates erection, and the transmission can be tested on the sub-frame before the whole gear is assembled in its final position The drive from the engine is through a simple cone clutch and a "Hardy" flexible coupling to a three-speed gear-box, which gives three forward and two reverse speeds. The top forward speed is on a direct drive through the gear-box and when using it the layshaft may be put out of gear if desired. A second gear-box is bolted to the three-speed gear-box. This contains the reducing gear. The first reduction is carried out by a bevel gear, and the second by a spur gear which drives on to shaft which carries the pinions for the

THREE-WHEEL WATER-BALLAST MOTOR ROAD ROLLER.

CONSTRUCTED BY MESSRS. BARFORD AND PERKINS, LIMITED, ENGINEERS, PETERBOROUGH.

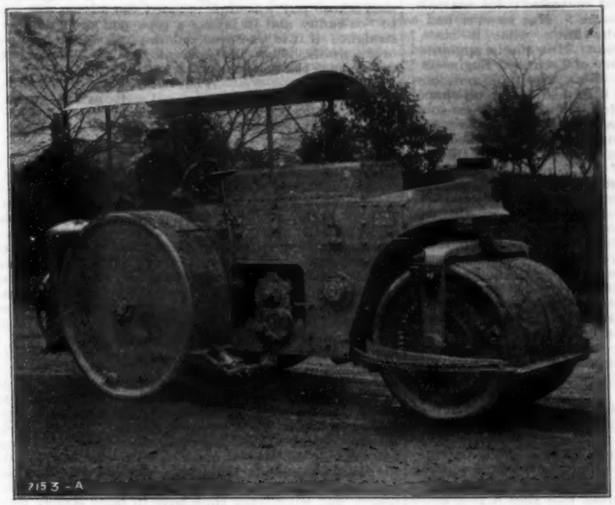


FIG. 1.

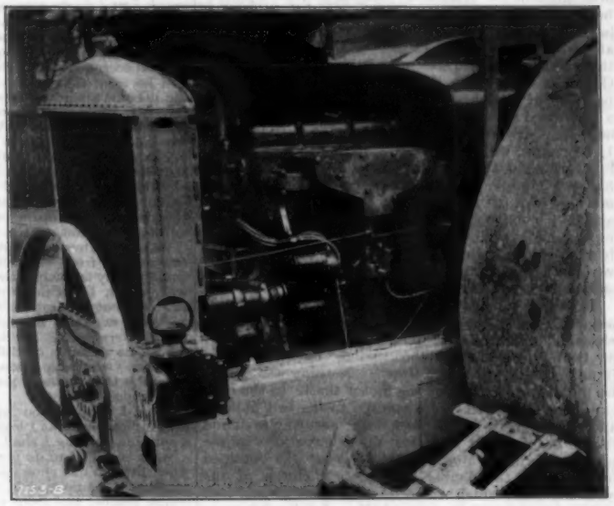


FIG. 2.

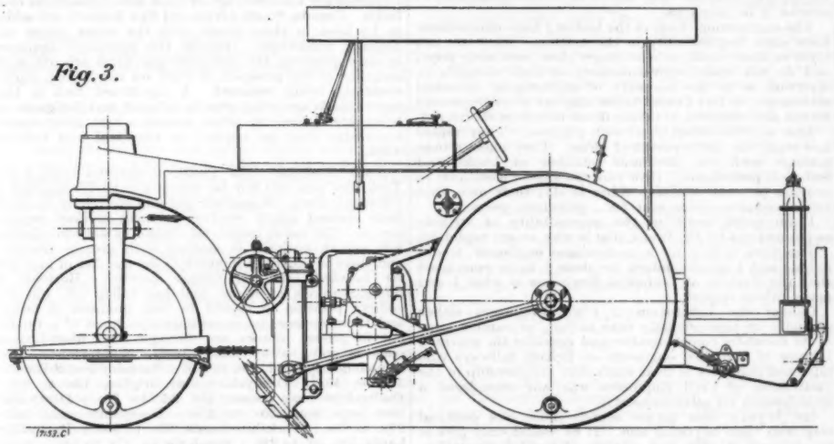


Fig. 3.

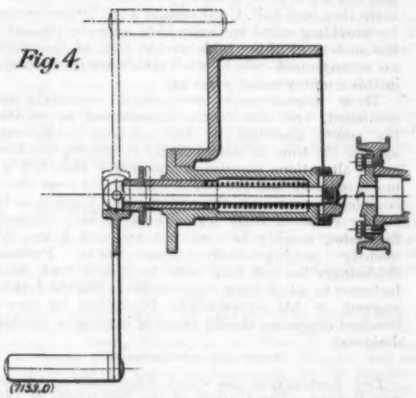


Fig. 4.

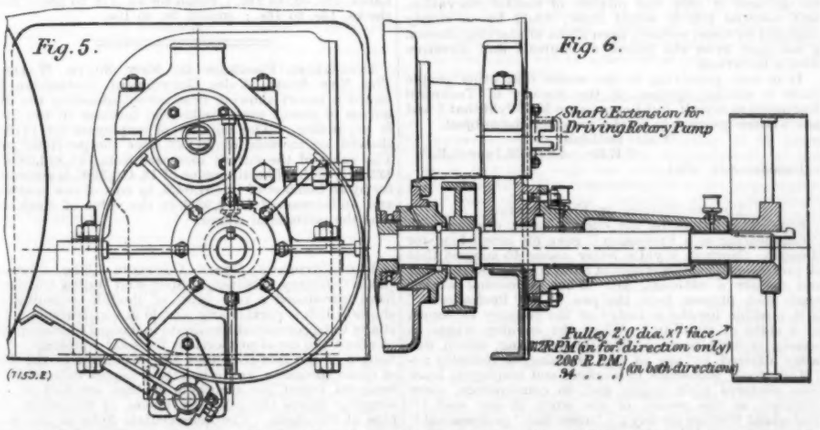


Fig. 5. *Fig. 6.*

final chain drive to the back rollers. This drive is by roller chain of 2¼ in. pitch, and with a breaking load of 70,000 lb. Slots are provided in the brackets supporting the transmission to allow for tightening the chain, when wear takes place. With the exception of the final chain, all gearing is enclosed and runs in oil.

The engine, which is built by Messrs. Peter Brotherhood, Limited, of Peterborough, is made under the Ricardo patents and embodies cross-head guides, heating of the air supply to the carburettor and admission of a small quantity of the exhaust gases to the mixture. In addition, overhead valves and a detachable cylinder head are fitted. A simple design of dust extractor is fitted on the air inlet. The engine, as already mentioned, is mounted on the sub-frame which carries the transmission. This sub-frame is underslung, and is bolted to the main frame. One incidental effect of the sub-frame is to bring the centre of gravity of the roller exceptionally low. The main frame is mounted on coil springs in the head and on axle brackets. This insulates the transmission, engine and radiator from shocks incidental to road rolling. In addition the drivers' seat is well padded and is carried on five spiral springs, which makes for comfortable riding over rough road surfaces. The frame has a three-point suspension and a similar form of three-point support is also employed for the transmission casing, consisting of the two gear-boxes bolted together.

The main particulars of the roller are as follows:—

	Ft.	In.
Diameter of front roller	4	0
Width of front roller	4	2
Diameter of back roller	5	6
Width of back roller	1	7½
Rolling width	6	9
Overlap of Rollers	0	4
Distance between back rollers	3	6
Wheel base	9	9½
Total length	18	1¼
Total width	6	9
Total height (awning)	9	3

	Miles per hour.
Speed, travelling	4
Rolling { Fast	2½
Rolling { Slow	1½
B.H.P.	40 (Petrol), 30–35 (Paraffin).
Water tank capacity	120 gallons.
Fuel storage capacity	50 gallons.
Water ballast	2 tons, 8 cwt.

20 deg. steel teeth on all enclosed gears.
Ball bearings on primary shaft.
Ball thrust washers on bevel gears.

In closing this description we should refer to Figs. 5 and 6, which show the arrangement of the removable pulley and bracket, which can be fitted to the roller for driving a stone-breaker or other machine. Finally it should be said that the side view given in Fig. 3 shows the method of attaching the "Price" patent scarifier, which is manufactured by Messrs. Aveling and Porter, Limited, of Rochester.

PLANING MACHINE STUDIES.

The conversion of rotary motion into reciprocal motion offers some complex problems to the designer of machine tools. The Versuchsfeld für Werkzeugmaschinen of the Technical High School at Charlottenburg commenced an inquiry into some of these matters in 1909. The work was interrupted by the war but afterwards resumed, and the methods applied and the results obtained are now published by Professor G. Schlesinger, chief of the department, in a quarto pamplet of 34 pages.* The machine selected was a horizontal planing machine by Messrs. Ludwig Loewe and Co., driven by an electric motor running at 1,460 r.p.m., with toothed gear and belting, the machine working at two cutting speeds of about 10 m. and 5 m. per minute, with a return speed of 15·4 m. The machine is of the Hendy type; it is actuated by a rack and pinion movement with a maximum stroke of 450 mm., and reversing is effected by a double-cone friction clutch. Professor Schlesinger had the help of various assistants at different periods, but his chief assistant was Dr. M. Kurrein.

The machine was first tested as supplied, with the aid of various appliances, diaphragm gauges and electrical apparatus, in order to obtain working data on the performance of the various parts. Various improvements were then tested. Nothing was gained by putting a flywheel on the motor shaft. In the next experiment lead discs were screwed to the belt pulleys, and the increase of the rotating masses was found to be beneficial in reducing the fluctuations in the power absorbed. More striking success was obtained by replacing the double-cone friction clutch of the reversing gear, which was originally made of cast-iron and weighed 5·8 kg., by a similar clutch of a magnesium-aluminium alloy weighing 2·5 kg.; both the maximum load and the mean load were then diminished, and the work to be done in reversing was reduced by more than one-half. Good results were further secured by providing spiral springs which were compressed by the movement of the table at the ends of the stroke, an arrangement which was satisfactorily developed in this country many years ago.

These improvements were tried separately and combined, and the results summarised by plotting the power absorbed by the machine in kilowatts against the time in seconds. By combining the three main alterations mentioned the power absorbed was much reduced, and the power fluctuations were almost completely overcome, the power curve keeping at the steady value of 0·51 kw., whilst it had originally fluctuated roughly between 0·5 kw. and 1 kw., frequently passing both these limits. Professor Schlesinger has not been able to induce tool manufacturers to adopt these improvements, but the detailed account of his experiments, illustrated by over a hundred diagrams, should prove of interest to machine designers.

The Institution of Civil Engineers; Awards for Papers.—The Council of the Institution of Civil Engineers has made the following awards for papers printed without discussion in the "Proceedings" for the sessions 1918–19 and 1919–20, publication of which has been delayed by conditions due to the war: Session 1918–19: A Telford medal to Professor E. G. Coker, F.R.S. (London); a Crampton prize to Mr. F. F. P. Biscoe, O.B.E. (Glasgow); a Manby premium to Mr. E. H. Lloyd, O.B.E. (Cairo); and a Telford premium to Mr. Rollo Appleyard, O.B.E. (London). Session 1919–20: A Crampton prize to Professor F. C. Lea, O.B.E. (Birmingham); and Telford premiums to Messrs. A. R. Horne, O.B.E. (Aberdeen), S. Blencowe (Buenos Aires), and W. J. Walker (Dundee) and R. Koivulehto.

Industrial Mobilisation in the United States.—At a time when the Washington Conference is still sitting, it is curious to read in an American journal (*The Iron Age*) that an exhaustive study is now being made by the Assistant Secretary of War, based on records of the War Industries Board and the Council of National Defence, in relation to the problem of industrial mobilisation. The Secretary of War, John W. Weeks, refers to this study in his annual report in connection with the discussion of the subject of preparedness for national defence. The problem of industrial mobilisation, it is added, has been divided into its elements relating to commodities, labour, power and transportation. Secretary Weeks points out that there must be the closest co-operation between the technical elements of national defence and the industries of the country. He says that the four most important fields for such development appear to be those relating to mechanical traction and transport on land, explosives production, chemical warfare and the control of the air. Plans initiated for preparedness of national defence contemplate a more complete state of preparation than at any period of peace time in the history of the country, but there still remains a great deal to be done. This subject is dealt with in greater detail by the different bureaus.

* Untersuchung einer Wagrecht-Stossmaschine mit Elektrischem Einzelantrieb-und Riemenzwischengliedern. by Professor G. Schlesinger and Dr. M. Kurrein. [Berlin: Julius Springer; price 16 marks.]

"ENGINEERING AS A PROFESSION."

To the Editor of Engineering.

Sir,—With reference to this correspondence and to Mr. Wyld's letter in your issue of 23rd inst., Mr. Wyld's methods of scarifying me are simple, and remind me of cheap journalese "Things we want to know" sort of stunt. The method is easy of imitation; for example, Who is Mr. Wyld? What is he? Has he ever had a technical training? Does he know what it costs? Or the hours of study it requires? How was he appointed general secretary of the Society of Technical Engineers? Did he form that society? If so, why? If not, how did it come about? Or was it formed on the off-chance that Mr. Wyld might get into Parliament? or do some political wire-pulling? What are they going to do? Are salaries of no direct consideration to the society? What would he do if he found after a severe training that he earned less than a "dud" plumber, a foreman pipe layer, the driver of a steam roller, an elementary school teacher, a school attendance officer, the man who superintends the operation of filling lavatory carriages in a large station, and so on?

As I said in my last letter, I am only willing to approach the matter from the point of view of civil engineers employed by municipalities, county councils and railways with which I am more particularly acquainted, and I say without hesitation that the technical staffs are wickedly exploited by these bodies, that men in clerical positions requiring no education beyond a secondary school, no training, no college, no pupilage, no expensive diplomas, who have trades unions and, due to the action taken by those unions, are to-day as highly remunerated as qualified engineers.

It is, I suppose, too late for me to change my profession, but much as I love the work and the life, if I see a suitable opening I shall do so.

As it is, all I can do now is to prevent loving parents, when little Willie shows some slight aptitude in putting together Meccano models, from imagining he has engineering genius, and from entering him into a profession which entails so much work and so little remuneration.

Other professions insist on its members having adequate remuneration, *e.g.*, doctors, lawyers, and even the Surveyors' Institute take action as to the conditions of service of its members.

The engineering chiefs of the bodies I have enumerated have some responsibility in the matter. Many are not loyal to their cloth, or soon forget their own early days, and do not make representations to their councils or directors as to the necessity of encouraging technical assistants; in fact I often think they are more impressed by the skill required in taking down letters in shorthand.

Low salaries defeat their own purpose. They retard and stunt the development of ideas. They make a man manage with the minimum number of books and technical periodicals. How can you expect assistants to provide (a most desirable thing to do) their own level and theodolite—mine cost 5*l.*, seventeen years ago.

I am quite aware of the impossibility of striking as pointed out by Mr. Wyld, that is why we are exploited.

The time is ripe for a professional engineers' trades union, and I should indeed be pleased to be convinced that the Society of Technical Engineers is what I and many others require.

Cannot the Institution of Civil Engineers either officially or semi-officially take action, or cannot some of its members come together and consider the matter? I know of two chief engineers on British railways who informed members of their staffs that membership of the Institution of Civil Engineers was not considered a qualification for advancement.

Mr. Wyld's clear future sounds more like political clap-trap than anything else. If he would only give it to us, and if only the picture of mental starvation, and material loss it would show, could be as clearly depicted as those we have been given of starving Russia. I am sure even the hearts of councils and directors would be wrung.

It is very gratifying to the writer that other people have a similar opinion of the Society of Technical Engineers as myself, but I can assure Mr. Wyld that I had not written previously to the press on the subject.

Yours faithfully,

"B.Sc., Assoc.M.Inst.C.E."

December 26, 1921.

To the Editor of Engineering.

Sir,—The letters in the current issue dealing with "Engineering as a Profession" gave me much food for thought. Norman Wyld's letter seems to suggest that all professional engineers should band themselves together and declare a national, &c. When a manual worker reads such phrases from the pen of a "Professional" is it possible for the industry of the country to return to a state of stability? What the country wants at present is more passages like the following, which was lately uttered by one of our captains of industry:—"How many thousands of workers and employers have been rendered more happy and, in consequence, more effective, as the results of the work of our staff?" (Industrial Welfare Society). Unless the "professional" men and the manual workers are prepared to cease writing about the methods of barbarism—for the pen is mightier than the sword—the halcyon days for which the nation is longing will still be a "mirage." The sympathetic and thoughtful employer sees and knows that those mighty organisations of employers and trade unionism have failed in their objects. It is a pleasure to read the reports of those meetings presided over by the Lords and Viscounts, who have the workers' welfare at heart. Originally the employers were to blame for so much dissatisfaction among the workers; they devoted too much time to workshop efficiency and allowed themselves to get out of touch with their employees, and thus lost control. As the old saying has it, "When the cat is away the mice will play." Until humane methods are adopted there will always be strife for the British mechanic as well as the British nomad, and also the unemployed. A remark I heard during a discussion in reference to the last-named being paid 75 per cent. of trade union rate of wages should carry weight. To men whose pay was thus reduced the advice was given to "ca-canny and in laying a pipe you need not lay it straight; if it is fractured put the bad side down." In other words, when the unemployed get 100 per cent. of the wage the response will come.

Yours faithfully,

Robert Keddie.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—Very few works are running at all this week. The whole of the heavy departments, including rolling mills, forges and press-shops, have shut down till the New Year, and those machine shops in commission constitute the exception rather than the rule. Correspondence arriving at steel and engineering works' offices during the holiday period indicates the possibility of a somewhat livelier demand in the near future. Both from home and overseas consumers' inquiries for common and special steels are distinctly more numerous, and though the tonnage named in individual orders represents only a mere fraction in comparison with output capacity, it is sufficient to assist in paying overhead charges and general works expenses. An interesting feature is that despite the slump in the alloy steel trade, largely resultant upon the existence of ex-Government stocks, France during the past six months, in face of an unfavourable exchange, has taken a substantial quantity of special steel, chiefly for her automobile industry. Several of Sheffield's rolling mills have been running almost solely on French orders, and what work they have in hand largely represents requirements from that source. Business is very patchy in the lighter trades of South Yorkshire. The outlook, however, is considered to be somewhat brighter. Inquiries are forthcoming for tools and implements from India. Canada, South Africa and New Zealand are asking to be kept in close touch with the latest prices and delivery conditions. Despite the optimism displayed in some quarters, the big armament firms are not at all sanguine at the prospect of work on the British cruiser contracts being resumed. A significant fact is that expert staffs are being greatly reduced, and designers are being transferred to other centres where their special knowledge may be applied to electrical and traction work.

South Yorkshire Coal Trade.—Deliveries from South Yorkshire pits will not be resumed until Wednesday or Thursday next. Meanwhile gas and electricity concerns have secured ample reserves to meet holiday requirements. The home industrial outlook is not stimulating, but export business is moving with greater freedom, and there is a distinct increase in the number of inquiries for forward sales on foreign account. Business in inferior grades of house fuel has fallen off, but the colliery position in regard to best qualities is firmer, and there appears no immediate likelihood of a further cut in prices. Slacks are stronger, and blast-furnace coke is going away more freely. Quotations:—Best branch handpicked, 39*s.* to 40*s.*; Barnsley best Silkstone, 38*s.* to 40*s.*; Derbyshire best brights, 35*s.* to 36*s.*; Derbyshire best house, 34*s.* 6*d.* to 35*s.*; Derbyshire best large nuts, 30*s.* to 32*s.*; Derbyshire small nuts, 27*s.* to 29*s.*; Yorkshire hards, 29*s.* to 30*s.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.*; rough slacks, 17*s.* to 18*s.*; nutty slacks, 15*s.* to 16*s.*; smalls, 5*s.* to 10*s.*

Industrial Progress in New South Wales.—The New South Wales Government Statistician has issued a report showing that notwithstanding the difficulties of recent years, industrial business in the State is expanding. The number of employees for 1919–20 showed an increase of 16,863 over the previous year. The value of the output increased from 104,803,081*l.* to 123,213,480*l.* The difference of 18,410,399*l.* is accounted for by an increase of 13,451,045*l.* in cost of raw material, and an increase of 2,714,921*l.* in the value of machinery plus the increase of wages.

The Coventry Chain Coupling.—The Coventry Chain Company, Limited, of Spon End Works, Coventry, have introduced a new type of flexible coupling for shafts which is particularly simple in construction. The shafts to be connected terminate in flanged half-couplings of about the usual proportions for solid couplings. The flanges of the half-couplings are machined in the form of chain sprockets, and a length of duplex roller chain is wrapped round the sprockets so that one-half of the coupling drives the other by means of the rollers and pins of the chain. The intermediate links of the chain pass between the coupling faces. The chain can be readily removed and replaced, and the fact that every pin takes its share of the drive permits comparatively large powers to be transmitted with a small o erall diameter. The coupling is made in 15 standard sizes to suit shafts from ¾ in. to 5 in. diameter, the smallest size being designed to transmit 0·8 h.p. at 100 r.p.m., and the largest 180 h.p. at the same speed. All sizes are perfectly balanced, and no lubrication is required. The Coventry Chain Company are making a speciality of small couplings of the type in question for driving magnetos, the necessary angular adjustment being readily obtained by shifting one flange relatively to the other.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

Workmen's Sacrifice to Assist Trade.—In the Cleveland pig-iron trade it has been the practice for many years for the ascertained price of iron for one quarter to regulate the percentage payable on the base rate for the succeeding quarter, and under ordinary circumstances, the price for the fourth quarter of 1921 would regulate the wages for the first quarter of 1922. The present critical situation of the trade has been the subject of very serious discussion between the Cleveland ironmasters and the workmen's representatives, and, as a result, it has been mutually agreed to ignore the forthcoming ascertainment so far as wages are concerned, and in lieu thereof, it has been further agreed that on and from January 1 next, the district percentage payable on the base rate shall be reduced from 77½ per cent. to 36 per cent. This departure from the normal operation of the sliding scale is evidence of the genuine desire on the part of the Cleveland workmen to render all the assistance in their power to the employers in their efforts to get the iron trade moving, it being fully recognised that great sacrifices must be made by all parties concerned if industry is to be restored to its normal activity.

Cleveland Iron.—Some inquiry for Cleveland pig-iron for delivery over periods next year is reported, and the opinion is expressed that the next cut in prices will be followed by a good deal of trade. The weekly market has not been held here this week. Official quotations are unchanged, No. 1 being 105*s.*, No. 3 G.M.B. 100*s.*, No. 4 foundry 95*s.*, No. 4 forge 90*s.*, and mottled and white each 85*s.*

Hematite.—With supply still in excess of needs East Coast hematite continues to tend downward in value, but producers speak very hopefully of the future. Further sales to South Wales are reported, and expectation is expressed of expansion of sales in other quarters. Makers are under no restriction as to what they may charge for their output, and in their eagerness to secure orders some firms might accept a little below the market quotations of 100*s.* for Nos. 1, 2 and 3, and 102*s.* 6*d.* for No. 1.

Foreign Ore.—In the continued absence of transactions, foreign ore prices are difficult to fix. It is understood that orders could be placed at round about 26*s.* c.i.f. for best rubio.

Coke.—Local consumers of coke complain that sellers are still asking too much for blast-furnace descriptions.

Manufactured Iron and Steel.—Works are closed for the holidays, and firms are badly off for orders, but it is gratifying to learn that one large establishment which has been closed for some little time is to be reopened early in the New Year. Among the principal home quotations are:—Common iron bars, 12*l.* 10*s.*; iron rivets, 14*l.* 10*s.*; soft steel billets, 7*l.* 10*s.*; medium steel billets, 9*l.*; hard steel billets, 9*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.* 10*s.*; heavy steel rails, 9*l.* 10*s.*; fish-plates, 14*l.* 10*s.*; and corrugated galvanised sheets, 17*l.*

AMERICAN PIG-IRON COSTS.—The Griffin Wheel Company, Chicago, has issued the following figures which are quoted in *The Iron Age*, New York, being estimates of the cost of making pig-iron in the three principal producing centres, based upon materials acquired at current market quotations:—

—	Pittsburgh.		Chicago.		Birmingham.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
		dols.		dols.		dols.
Ore	1·8	12·42	1·8	10·17	2·7	4·89
Limestone	0·4	0 48	0·4	0·48	0·4	0·40
Coke	1·0	4·50	1·0	7·00	1·6	8·00
Miscellaneous supplies and relining		0·81		0·81		0·94
Labour		1·08		1·08		1·35
Cost per gross ton ..		19·29		19·54		15·58

THE GERMAN PHŒNIX COMPANY.—Considerable interest attaches to the report of this concern. In spite of a total rise in wages from 356,250,000 to 766,680,000 marks, it shows an increase of profits from 68,940,000 to 128,590,000 marks, although the reserves put by have increased from about 2,000,000 to about 80,000,000 marks. The gross profits reach the formidable sum of 257,410,000 marks. In the beginning of the year the demand for all the company's manufactures surpassed by far the capacity of the different departments, which did not exceed 50 per cent. of the pre-war capacity. By degrees the demand subsided and prices receded below the maximum price of the Iron Industry Board, and fell eventually below the cost of production. It became necessary to materially reduce the output, short shifts were introduced and some of the company's works stopped altogether, more especially those in Düsseldorf and Hamm. Later, a better feeling set in. The company's production of pig-iron was 45 per cent. of the year 1912-13, and of steel about 60 per cent. The figures for finished products were on similar lines. The dividend was raised from 20 per cent. for the previous year to 25 per cent. In the new financial year the share capital has been increased by 139,000,000 marks.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—As the year draws to a close the depression of past months is as badly felt as ever, and the buying movement which was vainly hoped for has not set in. The competition which began recently has become very keen, and the local steelmakers are cutting prices so low in order to secure business that the margin has reached vanishing point. Even at to-day's prices consumers are loth to give out orders and only small lots are going through, although it is confidently anticipated that before very long buyers will again be entering the market and placing contracts in fairly respectable volume. The requirements for shipbuilding purposes are still small, but every reduction in the price of steel brings us nearer to the time when the quotations for new tonnage will be such as to allow of shipowners again giving out orders for new vessels. The black sheet makers are still very quiet, and only a limited amount of business is being booked as buyers continue to play the waiting game. The foreign inquiry for galvanised sheets is better, but the improvement in orders is very slow. Export in general is not a shadow of what it might be, but signs are not wanting that after the turn of the year an opening out is highly probable, as freights are tending downwards. Current quotations may be taken as under:—Boiler plates, 14*l.* per ton; ship plates, 10*l.* 10*s.* per ton; sections, 10*l.* per ton; all delivered Glasgow stations. The latter two quotations are not firm, as a good specification will induce a better price. The quotation for steel sheets is unaltered.

Malleable Iron Trade.—In the West of Scotland malleable iron trade there has been practically no change in the conditions prevailing during the past few weeks. The amount of work on hand is very small and is quickly overtaken, with the result that the various establishments are running intermittently. Recent reductions in prices have not brought out buyers, who consider that lower levels must be reached before they can profitably do business. To-day's prices are based on 12*l.* 10*s.* per ton for "crown" bars, delivered Glasgow, and the bar iron makers are unwilling to consider another cut until oncosts again become easier.

Scottish Pig-Iron Trade.—The state of the Scottish pig-iron trade has not improved, and although there are only a mere handful of furnaces in blast the output is ample for all requirements. The amount of hematite iron being used at the steel works is very small, and there are sufficient stocks on hand to overtake all demands without any more being manufactured at present. Foundry iron is being consumed very slowly, and the price of No. 1 quality is 6*l.* per ton, and No. 3 5*l.* 15*s.* per ton, both ex-makers' works, while hematite is called 6*l.* per ton delivered at the steel works.

Clyde Shipbuilding.—The shipbuilding returns for the past month are not very satisfactory, and yet when the general state of trade is taken into account the industry is no worse off than its neighbours, and is much better off even than some. For the year to date the number of vessels launched on the Clyde was 238, making a total tonnage of 511,001 tons. These figures do not compare too favourably with the 330 vessels of 672,438 tons of 1920, nor yet with the 370 vessels of 756,976 tons of our record output year 1913.

Alloa Shipbuilding.—An announcement has just been made that the recently reconstructed Forth Shipbuilding and Engineering Company, Limited, will resume partial operations at both Kelliebank and Jeffrey's yards, Alloa, on Wednesday, January 4, 1922. It is now about nine months since work ceased at these yards, and much satisfaction is expressed in the district at the decision to re-open next week. Although only about 500 or one-third of the workers will find employment, meantime, the remainder will be absorbed as soon as possible after conditions improve.

THE NORWEGIAN INTERNAL-COMBUSTION ENGINE INDUSTRY.—This industry in Norway is at present labouring under very adverse circumstances, so much so in fact that, with one exception, the works have closed down. This does not apply to the large engineering and shipbuilding concerns which manufacture Diesel engines for the vessels they build, but to the class of undertakings which manufactured engines for the large fishing vessels, of which so many were laid down and equipped during the fishing boom caused by the war. The demand has now almost entirely subsided.

FEED WATER OIL GAUGE.—For the rapid testing of the amount of oil in boiler feed water Messrs. Frederick A. Pullen and Co., of 58, Harleyford-road, Vauxhall, S.E. 11, are introducing the Martin gauge which forms part of a testing set supplied by the firm for rapidly detecting oils, acids, &c., in boiler feed water. The set comprises all the necessary test tubes, dropping bottles and chemicals, &c., and is arranged in a cabinet which can be fixed to a bulkhead, being intended primarily for use on ships. The oil gauge consists of a graduated glass tube with an opaque white bottom in the centre of which is a small black spot. The feed water is poured into this tube until the black spot is on the point of disappearing in a good light, when the height of the water gives a direct reading on the scale of grammes per gallon of feed water. The oil present should never exceed 3 grammes per gallon of feed water, 1 gramme to 1½ grammes being the usual maximum limits desirable. The Martin gauge offers a ready means of determining the amount of emulsified oil present, and this simple and very sensible check can be carried out frequently without inconvenience.

NOTICES OF MEETINGS.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Tuesday, January 3, at 7 p.m., at the Chamber of Commerce, New-street, Birmingham, when Mr. W. W. Hackett will read a paper entitled "Experiments with Weldless Steel Tubing as Used in Construction."

THE INSTITUTE OF COST AND WORKS ACCOUNTANTS.—Wednesday, January 4, at 7 p.m., at the Hall of the Institute of Chartered Patent Agents, Staple Inn Buildings, Holborn, when a Lecture will be given by Mr. H. G. Jenkins, F.C.W.A., on "Financial Planning." The chair will be taken by Mr. J. M. Fells, C.B.E., F.C.W.A.

THE INSTITUTION OF ELECTRICAL ENGINEERS: WIRELESS SECTION MEETING.—Wednesday, January 4, at 6 p.m. (light refreshments at 5.30 p.m.), "High-Speed Wireless Telegraphy," by Lieutenant-Colonel A. G. T. Cusins, Royal Corps of Signals. A demonstration of traffic working will be given by the author.

THE INSTITUTION OF SANITARY ENGINEERS.—Wednesday, January 4, at Caxton Hall, Caxton-street, Westminster, S.W. 1, when the Presidential Address will be given by Mr. J. H. Blizard, M.Inst.C.E. The retiring president, Mr. Nandy Hoskins, will take the chair at 7 p.m.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, January 5, at 6 p.m. Lecture on "Single and Three-Phase Commutator Motors with Shunt and Series Characteristics" (with experiments), by Dr. S. Parker Smith, Member. The lecture will be followed by a discussion.

THE ROYAL AERONAUTICAL SOCIETY.—Thursday, January 5, at 5.30 p.m., at the Royal Society of Arts, John-street, Adelphi, when Wing Commander W. D. Beatty, C.B.E., A.F.C., will read a paper on "Specialised Aircraft."

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, January 6, at 8 p.m., at Caxton Hall. Lecturette, "Stone and Marble-Working Machinery," by Mr. A. E. Bingham (Member).

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 6, at 6 p.m., Joint Meeting with the Society of Chemical Industry. "The Co-operation of the Engineer and Chemist in the Control of Plants and Processes," by Mr. G. M. Gill, Member.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS.—(MANCHESTER CENTRE).—Friday, January 6, at the College of Technology, Manchester, when a paper will be read by Mr. C. J. Allen, Associate, London, entitled "Notes on the Influence of Design on Express Locomotive Performance."

"ENGINEERING AS A PROFESSION."—ERRATUM.—In Mr. A. C. Purday's letter on this subject, on page 851 of our issue of December 23, there was a typographical error. "At 16 years of age I received the large sum of 30*s.* per week," &c., should have read "as sixteen years ago I received," &c.

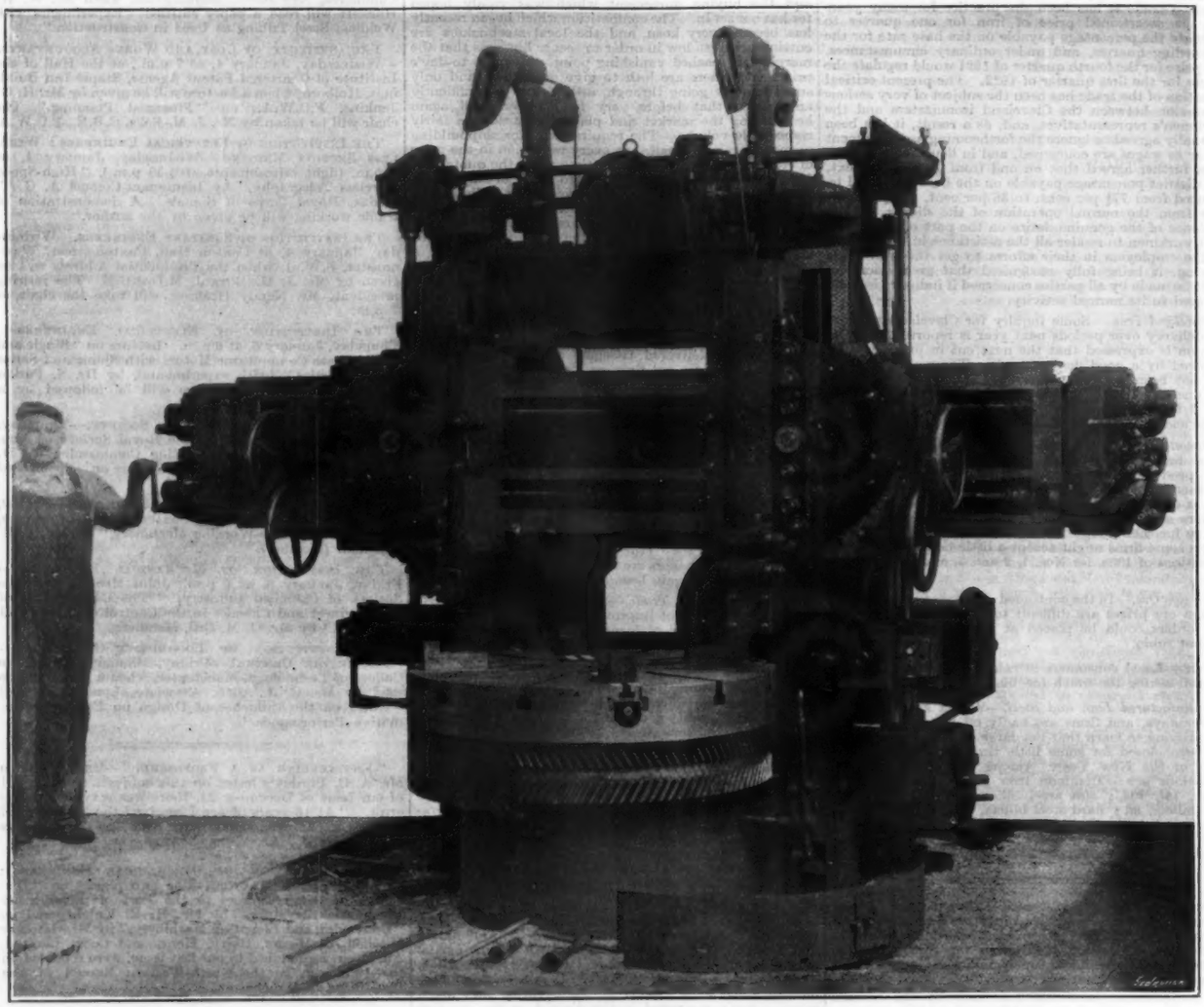
THE INSTITUTION OF MECHANICAL ENGINEERS: NORTH-WESTERN BRANCH.—The two papers on "Discharge of Grain Cargoes in the Port of London by Pneumatic Elevators," by Mr. R. E. Knight, and on "Conveying and Elevating Machinery," by Mr. Gardiner Mitchell, of Messrs. Barry, Henry and Cook, Limited, Aberdeen, reproduced in our last issue, were repeated on the 19th inst. to the North-Western Branch of the Institution in Manchester.

ANGLO-AUSTRALIAN WIRELESS SERVICE.—With reference to the successful interchange of wireless messages between England and Australia recently reported, it is stated by the managing director of the Amalgamated Wireless (Australasia) Company, that preparations for a cheap and rapid service of direct communication have been completed. All the capital cities of the Australian States will be able to take advantage of this service, and a project is on foot to provide for the growing traffic with North America by a station in Western Canada. The Australian high power station and the corresponding stations in England will be equipped with the most modern apparatus for duplex automatic transmission and reception with distant control, and the feeder stations at the other capitals will be similarly equipped, but with smaller power. The wireless stations will be situated outside the cities; but the actual operating staffs will be in the heart of each city, and will send and receive messages by means of distant control apparatus.

GERMAN BAUXITE SUPPLIES.—We read in *The Iron Age*, New York, that Germany's bauxite production before the war was so insignificant as to render her virtually dependent on French supplies, the total requirements in 1913 amounting to about 38,000 tons, valued at over 2,000,000 marks. With a view to becoming independent of foreign bauxite, steps were taken during the war and since to explore domestic bauxite fields. Valuable deposits were ultimately found in Hessen. They are being worked by the Bauxitwerke A.G., at Giessen, and represent the only mines in operation in Germany. The principal consumer of the ore is the State-owned Lauta works, having an annual output capacity of 14,000 tons of aluminium, the rest being taken by other electric smelting works. The present average monthly output, representing the production of 15 mines employing about 300 men, is 1,200 tons, but there is claimed to be nothing in the way of increasing output by sinking new shafts and employing additional labour. In accordance with the growing demand, it is planned to bring production to 20,000 tons during 1922.

53-IN. TYRE MOULD AND CORE BORING AND TURNING MILL.

CONSTRUCTED BY THE NILES-BEMENT-POND COMPANY, NEW YORK, U.S.A.



We illustrate above a powerful 53-in. boring mill intended especially for turning and boring moulds and cores for railway wheels. This machine is constructed by the Niles-Bement-Pond Company, of New York, whose London offices are at 25, Victoria-street, S.W. 1. It is, of course, suitable for a wider range of work than the special class for which it is primarily intended.

The actual swing is 54 in., the table diameter being 50 in., and the maximum height under the tool-holders 30 in. The table is driven by herring-bone or spur gear, the example illustrated having the former, as may be seen from the view of the machine, in which it appears with part of the table gear cover removed. The table spindle is carried in two parallel bearings, both bushed with bronze. The upper bearing is 11 in. in diameter, and the lower 9 in. in diameter. In addition, a vee ring track is provided under the table, this having an outside diameter of 32½ in. and an inner diameter of 24 in. The herring-bone gear for the table has 120 teeth, of a face width of 7 in., and 2½ D.P. Thirty-two speeds are arranged, with speed control from either side of the machine, the motor being carried on a plate at the back of the housings. Its power is transmitted through a double-ended clutch, which provides a friction clutch on the fast side and jaw clutch on the slow side, giving two mechanical master changes of speed, with 16 speeds in the controller, making the 32 mentioned above. The lubrication of the table is arranged for by means of a pump which forces the oil through the bearings and over the vee track. The table has T-slots and is furnished with four independent jaws, each jaw being carried on a corrugated block fitting in planed grooves.

The housings are of box form, double-webbed, and with faces 9 in. wide, the thickness in the body being 7 in. They are securely fastened to the bed, on which they have a bearing 4½ in. long. At the top they are firmly held by a heavy top brace. The cross-rail is of box-girder form and is 6⅝ in. thick at the housings where the bearing faces have a length of 24½ in. The thickness at the centre is 14½ in., while the face is 22½ in. wide. The cross-rail has three faces, as will be seen from the figure, the traversing screws for the saddles being located between the bottom two. The cross-rail is raised and lowered by power, by means of a motor mounted on the top brace working, through reduction gears, an horizontal shaft which drives the elevating screws in the housings by means of enclosed bevels. The maximum height under the cross-rail is 33 in. from the table.

The saddles have a length of bearing on the cross-rail of 26½ in.; they are provided with taper gibs for taking up wear. A clamp bolt is arranged for clamping them when the tool bars are being fed. The bars can be swivelled on the saddles by means of arc worms of large radius, through 30 deg. either side of the vertical. The tool bars are of rectangular section, and are carried in slides 28 in. long. They can be clamped in any position. At the lower end they are fitted with tool holders with straight shanks, which can be readily removed to make place for special boring bars. The tool-holders have a width of 5⅞ in. and a shank diameter of 3½ in., the normal size tool taken being 1¼ in. The bars have a width of 8·4 in., and a maximum travel of 22 in. The maximum height from the table to the underside of the saddles is 30 in., and to the underside of the bars 36 in., the tool-holder projecting 6 in. below the latter. The tool bars are independently counterbalanced by weight and cable passing over pulleys seen above the machine.

The feed is from the main motor, through a feed-box and enclosed bevels to vertical shafts, and thence to the feed screws in the upper part of the cross-rail. The feeds are reversible and independent for the two bars, both in direction and amount, for vertical, horizontal, and angular feeding. Six feeds are provided, viz., $\frac{1}{32}$ in., $\frac{1}{16}$ in., $\frac{3}{32}$ in., $\frac{1}{8}$ in., $\frac{3}{16}$ in. and $\frac{1}{4}$ in. per revolution of the table. Fast traversing of the bars and saddles is arranged for by the motor on the top brace, through an horizontal shaft, bevels, &c. Both the feed and fast traverse can be controlled on each side of the machine. There are three control levers at each end of the cross-rail. The upper one reverses either the feed or fast traverse of the tool bar. The lower one reverses the feed or fast traverse of the saddle. The third, or central, lever engages either the feed or the fast traverse to the saddles and tool bars. It is thus impossible to engage feed and fast traverse at the same time for one member. The levers are arranged to throw over in the direction in which the part is required to move. Hand wheels are provided on the saddles for both feed and saddle traverse.

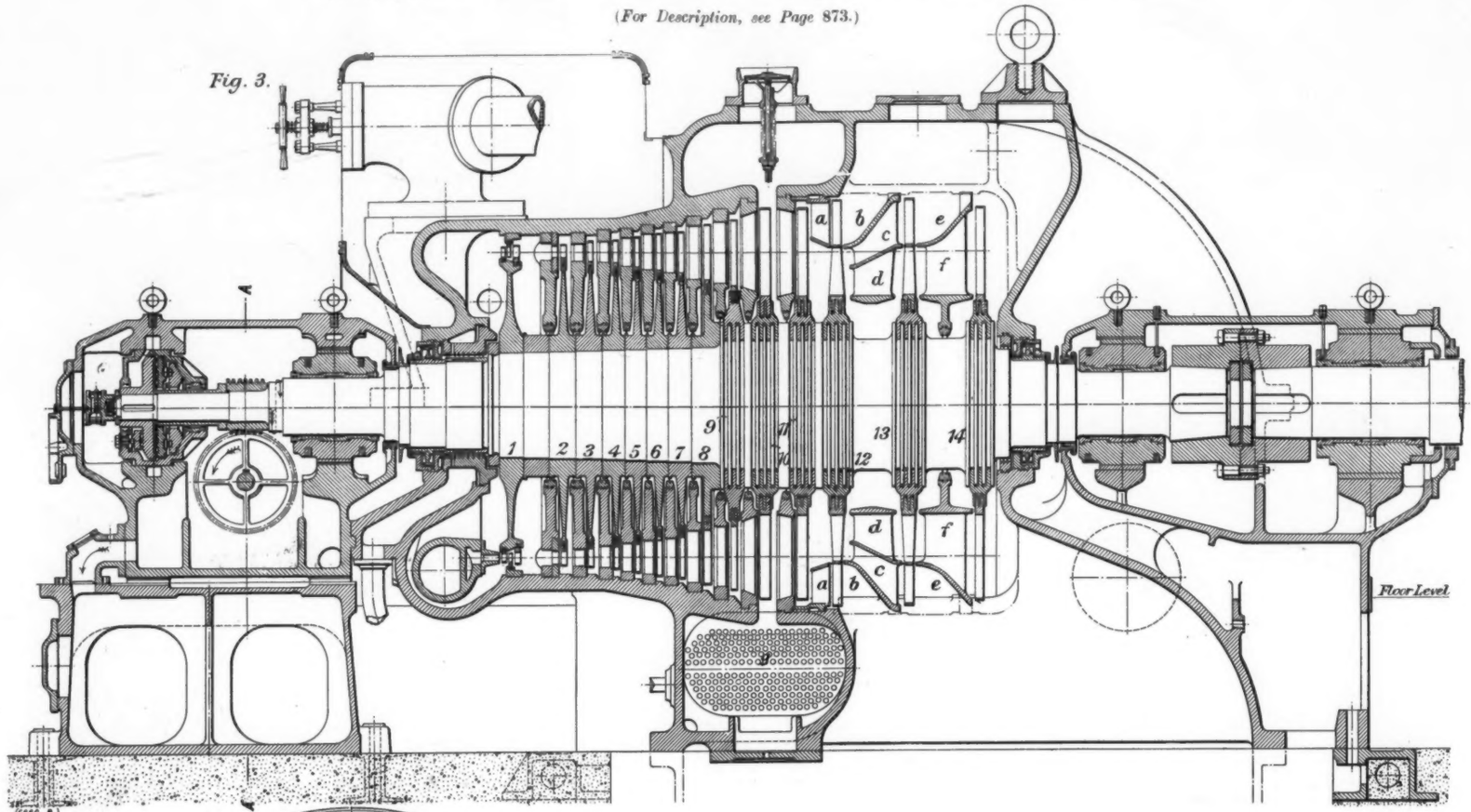
The machine is ordinarily arranged to be driven by a 10 h.p., 220-bolt direct-current shunt-wound, semi-enclosed motor, with a range of 400 r.p.m. to 1,600 r.p.m. This is provided with enclosed non-reversible magnetic control panel, enclosed type field rheostat and two start and stop push button stations, one being on the front of each housing. The elevating and fast traverse motor is of 3 h.p. for 220-volt direct-current and running at 1,150 r.p.m. It is of the compound-wound semi-enclosed type with drum controller.

12,500 KW. TURBO-GENERATOR FOR THE LIVERPOOL CORPORATION ELECTRICITY WORKS.

CONSTRUCTED BY MESSRS. METROPOLITAN VICKERS, LIMITED, ENGINEERS, TRAFFORD PARK.

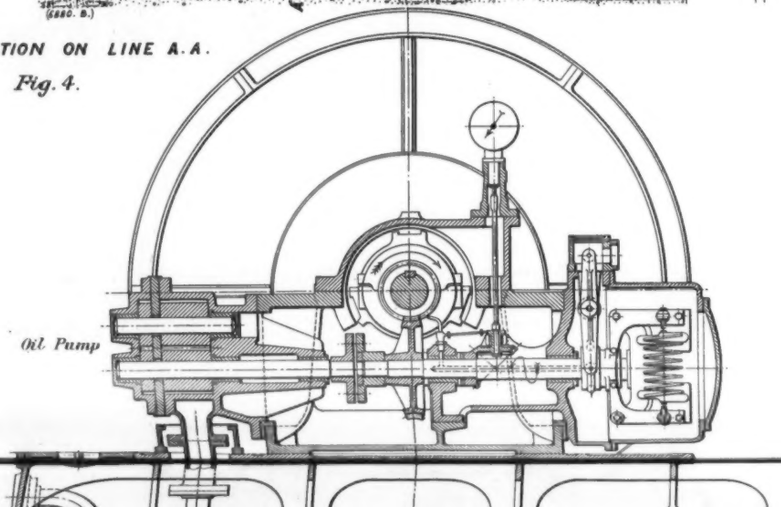
(For Description, see Page 873.)

Fig. 3.



SECTION ON LINE A.A.

Fig. 4.



ARRANGEMENT OF GLANDS.

H.P. END.

Fig. 7.

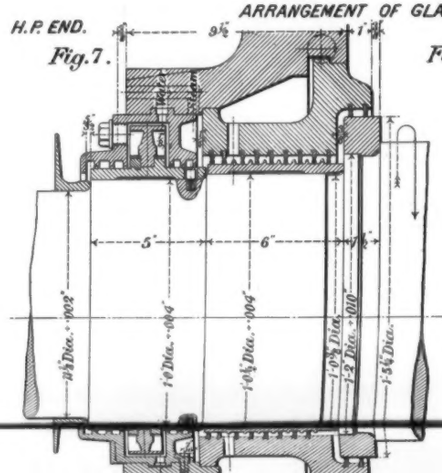
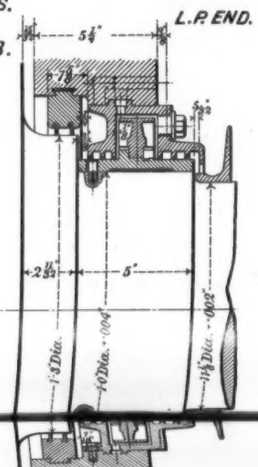
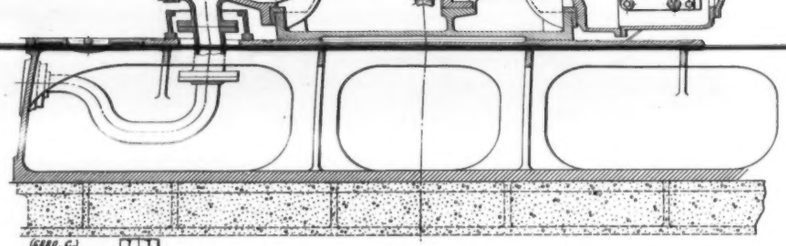


Fig. 8.

L.P. END.





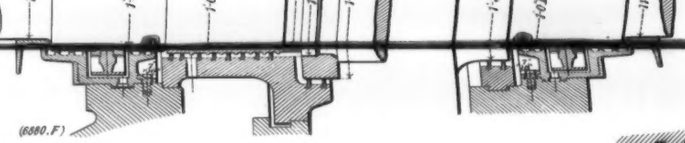


Fig. 9. DETAIL OF GROOVES.

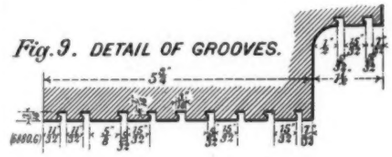


Fig. 5.

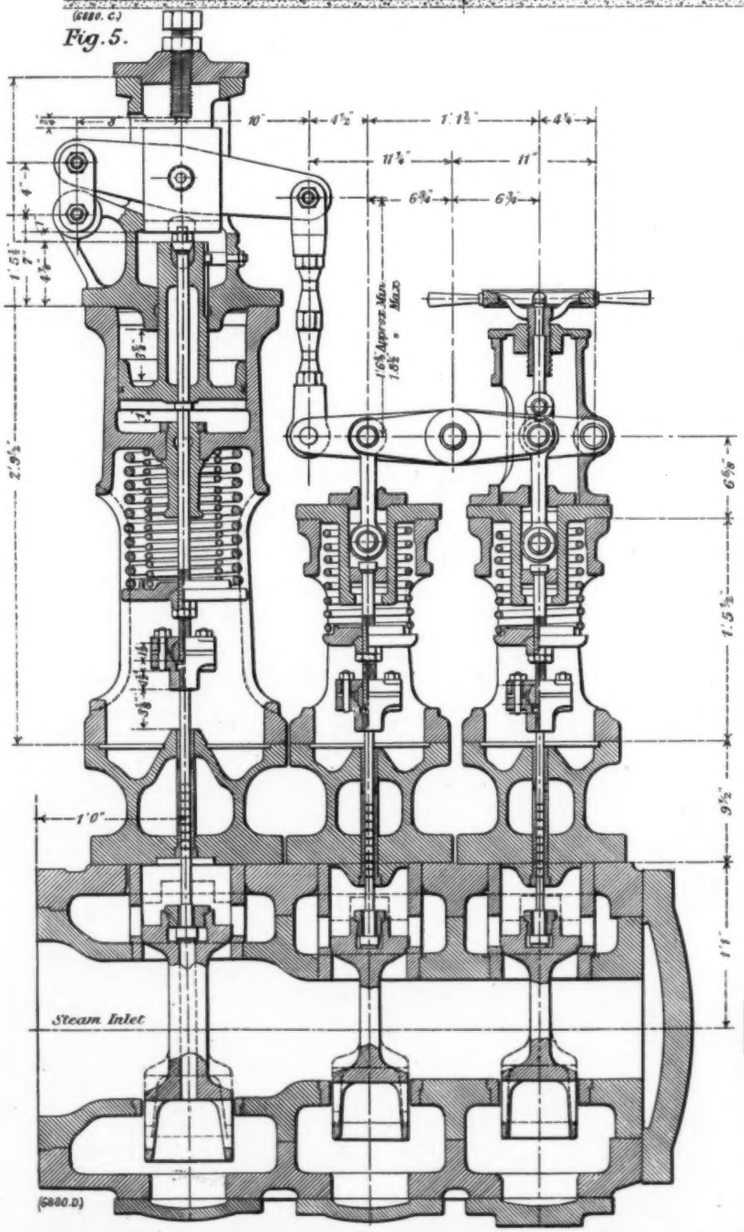


Fig. 6.

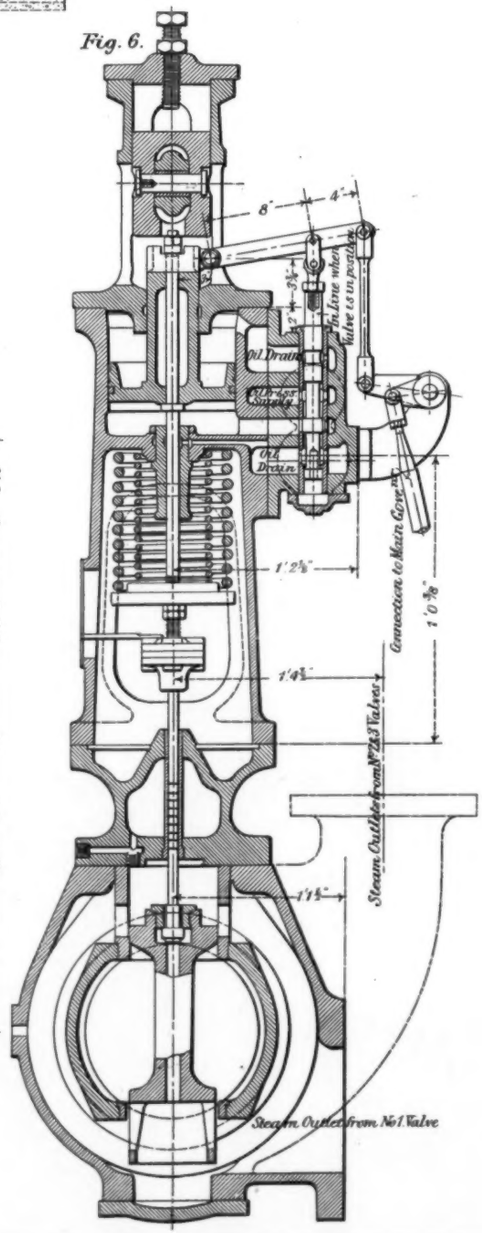


Fig. 10.

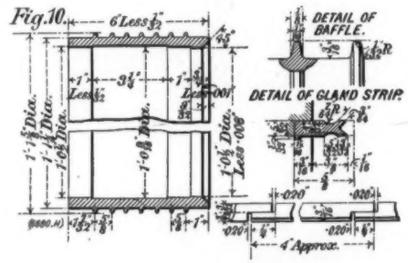


Fig. 11.

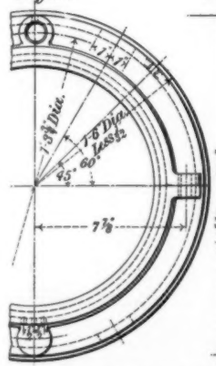


Fig. 12.

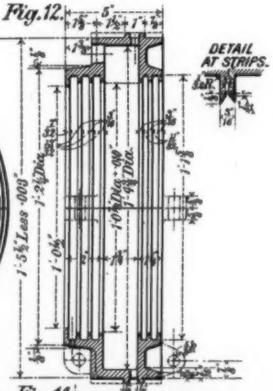


Fig. 13. HALF SECTION A.A.

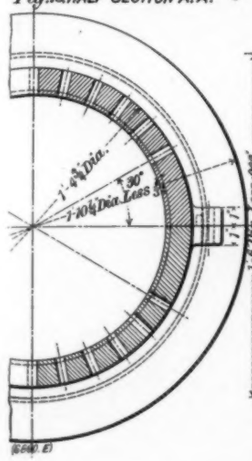
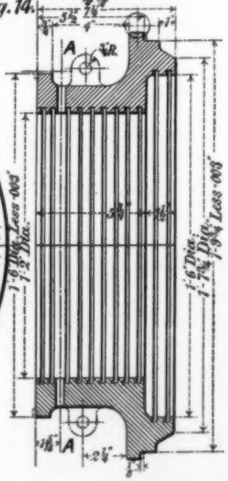


Fig. 14.



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With a Two-Page Plate of a 12,500 *KW. TURBO-GENERATOR FOR THE LIVERPOOL CORPORATION ELECTRICITY WORKS.*

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 887.

ENGINEERING.

FRIDAY, DECEMBER 30, 1921.

THE DISPOSAL OF LONDON REFUSE.

THE disposal of city refuse is one of those problems for which there exists no single solution which is the best for all times and places. The technical questions involved are so difficult, and they are so often overshadowed by considerations of a financial or administrative nature, or influenced by the special conditions of a particular district which may moreover change from year to year that uniformity of treatment is not to be expected. Nevertheless, as is the case with all the problems of the engineer, necessity has got to be met by action. Refuse has got to be disposed of if the health and comfort of the community are to be safeguarded, and every engineer responsible for the sanitary service of a particular area has to discover the method most appropriate to the conditions with which he has to deal. Under such circumstances there is everything to be gained by periodical conferences of the men charged with the duty of adapting means to ends in different localities so that the experience of each may be available for the guidance of all. Some two years ago the Westminster City Council, impressed with the importance of deciding upon the best way of dealing with London house refuse in the light of present knowledge and facilities, convened a conference of the Metropolitan Borough Councils to discuss the matter, and the conference appointed a committee, under the chairmanship of Alderman J. T. Watson of St. Marylebone, to make investigations and to report. Territorially, the committee was representative enough of the various boroughs, but comprising, as it did, only four engineers to ten aldermen and councillors, it can hardly be said that it carried the same technical authority as it would have done if the numbers had been reversed.

The final report of this committee has now been issued, and it contains much interesting information on the questions with which it deals. The Administrative County of London covers an area of 117 sq. miles and includes a population of 4,483,000 persons. It is divided into 28 metropolitan boroughs and the City of London, and the council of each city and borough is responsible for the collection and disposal of the refuse from its own territory. The aggregate amount of refuse which has to be disposed of annually is about 1,500,000 tons, or about 5,000 tons for every working day throughout the year. A total of 1,320 vehicles are employed in its collection. It will come as a surprise to most Londoners to know that practically 80 per cent. of this huge quantity of refuse is merely dumped in its crude form on low-lying land and in disused clay-pits and quarries in the neighbourhood of London. Six hundred and seventy thousand tons are taken away annually to the dumps by barges and 250,000 tons by rail, 280,000 tons are burnt in destructors, and the balance of 300,000 tons is disposed of at local shoots, or by sale, &c. It is estimated by the committee that the total cost of refuse disposal throughout London, exclusive of the cost of collecting it, is approximately 8*s.* per ton, or about 600,000*l.* per annum.

No one can maintain that these facts are creditable or even satisfactory. If dumping 1,200,000 tons of offensive and unsightly refuse annually on to waste land is the best that can be done it is a very poor best. It is a custom which has grown up in a natural way, and which has apparently endured more from considerations of simplicity and repugnance to change than from even the justification of cheapness. Practically all the available dumping grounds are in the hands of a few contractors, and the municipalities are thus compelled, in default of any alternative form of disposal, to employ those contractors to take their refuse at prices governed by the law of supply and demand. The operation of this law appears to have become irksome, and in July last year, the conference to which we have referred passed a resolution that Parliamentary powers should be obtained for the compulsory acquisition of land for refuse disposal, so that municipalities could carry out their statutory obligations independently of contractors. Even were such powers to be obtained, and presuming that they should result in a cheapening of the cost of disposal, the resolution is only of a temporising nature and shows a lamentable want of vision. At no far distant date the dumping of crude refuse on unoccupied land must come to an end, either because there is no more land available, or more probably because these great dumps will be recognised as a nuisance and a menace to public health. They are essentially noxious in their nature, and constitute breeding grounds for flies, rats and other vermin.

This appears to be the view taken by the committee. They state in so many words that "it is a question for the most serious consideration of each council concerned whether the time has not come for the abandonment of the easier but more costly and insanitary methods of refuse disposal" at present so largely depended upon. They fully realise the reluctance to incur capital expenditure at the present time, but suggest that the borough councils should break away from old methods, and introduce, experimentally at first, others which "we think must commend themselves as desirable, and which we confidently predict will in practice be found to be financially advantageous." The wording of this part of the report is extremely polite and guarded, but we think that their conclusions might be fairly paraphrased by saying, "Existing methods of disposal by dumping are obsolete, insanitary and costly. There are several ways which are vastly cheaper and better, and each authority should at once adopt that which is best suited to its particular needs."

Such an exhortation would be of little value were it not coupled with practical indications of the directions in which some alleviation of the present state of affairs may be found. The committee, although not advocating any particular method as suitable for general adoption, give enough information in their report to show that there are several alternatives worthy of close consideration. Dumping the refuse out at sea is regarded as impracticable, chiefly on the grounds of expense. Burning it in destructors has been found eminently satisfactory in some places, but it is pointed out that cases where this plan has been abandoned on account of unsatisfactory, insanitary or uneconomical working are not unknown. To deal with the whole of London's house refuse by means of destructors would involve a capital expenditure of not less than 1,250,000*l.*, and taking into account the working costs and the removal of clinker it is estimated that the total net cost of disposal by destructor would not be less than 8*s.* per ton under the most favourable circumstances. One gathers that the committee has very little faith in destructors as a general solution of the problem, the steam they may supply is regarded as of small practical account and the clinker, which amounts to some 33 per cent. of the weight of the refuse burnt, is a liability rather than an asset. They summarise their opinion to the effect that the part played by the destructor in future will be, not the burning of all refuse, but only that portion of which no further use can be made, a sentence which foreshadows their views on the advantages of salvaging.

In coming to this conclusion the committee have no doubt given full consideration to the good results obtained from the Hornsey destructor plant, particulars of which are included in their report. This deals with 23,000 tons of refuse yearly at a cost of 6*s.* 4*d.* per ton exclusive of collection and cartage. The clinker amounts to about 7,000 tons per annum, and ever since the plant was started thirty-two years ago, clinker has been considered as a valuable by-product and has been completely utilised for making roads, footpaths, paving slabs, building foundations, mortar and artificial asphalt. The success which has been attained in these directions is largely due to the enterprise of Mr. E. J. Lovegrove, the engineer and surveyor of the borough. The steam power developed by the destructor

plant is utilised for driving various machines, in connection with the works. Another destructor mentioned by the committee is the Ramsay, an experimental installation of which is working at Wandsworth. This is claimed to have a residue amounting only to 15 per cent. of the refuse consumed and consisting of a hard clean brittle slag like glass.

As an alternative to incinerating the refuse in a destructor the Boroughs of Southwark, Bermondsey and Hampstead have adopted a scheme of pulverising it with a view to its subsequent beneficial or, at any rate, innocuous use on the land. The Southwark plant, which was started over fifteen years ago, now contains six rotary crushers, each driven by a 50 b.h.p. motor, and works in a populous district. The house refuse is deposited in front of the crushers and in the process of feeding the latter such materials as tins, mats, oilcloth, boots, bottles, &c., are extracted as far as possible. Such of these as are saleable are sold, and the remainder are burnt in a furnace. The refuse, after passing through the crushers, is loaded into railway wagons by means of conveyors and is sold as a low-grade manure. During the year ending March last, 18,789 tons of crushed refuse were produced at a cost of 3*s.* 11*d.* per ton. The sale of this, together with the sacking, tins, &c., removed before crushing, produced a sum of over 4,100*l.* towards the cost of refuse disposal during the year in question. The council also realised over 3,500*l.* by the sale of their road sweepings, ashes, &c., these two items reducing the gross cost of refuse disposal for the year from about 5*s.* 11*d.* per ton to a net figure of 3*s.* 6*d.* per ton. The gross cost of disposal will be seen to be far below the general metropolitan average of 8*s.* per ton, so that pulverising would seem to be an economical process quite apart from the revenue from the final product. At Bermondsey, where 320 tons per week are crushed, the results are not so good as at Southwark, partly because the sale of the crushed product has not been developed, but even so the total cost is slightly less than that incurred by barging away the crude refuse.

The investigations of the committee lead them to the final conclusion that the great bulk of London house refuse can be converted or separated into marketable commodities and sold in relief of the rates. Typical London refuse contains by weight 47 per cent. of ashes, 25·55 per cent. of breeze and cinder, 13·15 per cent. of paper, straw, fibrous and vegetable matter, 9·75 per cent. of dust and dirt, 1·72 per cent. of crockery, and less than 1 per cent. of any other of the remaining seven constituents, namely, metals, bottles, rags, bones and offal, glass, coal or coke. A great deal of this mixture has a definite and considerable market value if only it could be offered to customers in a suitable condition and free from the admixture of things which they do not want. Sorting or salvaging costs money, but so long as it costs less than barging or railing the material away to a dump or incinerating it in a destructor, the salvage could be economically given away if no purchasers could be found for it.

The most elaborate plant for separating London house refuse into its saleable components is that recently constructed by the Marylebone Borough Council to the designs of Mr. James Gair, the highways engineer of the borough. The refuse is dumped by the collecting lorries into large concrete pits, whence it is lifted by a grab-crane to a screening plant. Here it is separated into four grades of material, viz., fine ash or dust, cinders or coal, waste paper, bottles, rags, bones, &c., and tins and iron articles. The fine ash which amounts to 30 per cent. or so of the whole is pulverised and has a saleable value as a fertiliser. The cinders and breeze when separated are also valuable, and markets can be found for waste paper, rags, bones, bottles and glass, solder and tin cans. The separation of these is done by sorters as the material passes over a belt conveyor. The cans, after being de-tinned are baled by presses for transport. The unsaleable residue of the refuse is burnt by forced draught under a boiler and raises the steam required to operate the machinery.

The Marylebone plant will deal with 180 tons of refuse per day, and cost complete 11,722*l.*, including additions to and alterations of buildings. It has hardly been running long enough to provide reliable figures as to the net cost of the disposal of refuse by the means employed, but with energetic and capable management it should be a valuable asset to the borough. The committee evidently regard the system with approval, and though they express the opinion that the decision as to the most suitable method of disposal for any particular borough is a matter for the council of that borough, they elsewhere recommend that the "closest and most serious consideration" should be given to salvaging as against the disposal of crude refuse by dumping. Indeed one can hardly study the report without coming to the conclusion that salvaging is looked upon as the most economical and practical way of dealing with London house refuse generally. The health services of the metropolis are quite adequate to seeing that it is carried out in a manner innocuous to the operating staff and inoffensive to the neighbourhood. The Westminster City Council are to be congratulated in having convened the conference which led to the investigation and report of the committee, and it is to be hoped that the matter will be pursued until more efficient methods of dealing with the house refuse of London are general throughout the metropolis.

COAL AND WATER POWER IN CANADA.

A good many reports have in the last few years been concerned with the economic production of power and the conservation of natural resources. These have been partly the result of the war, which directed an unusual attention to questions of this kind, and partly due to anxiety caused by prodigal waste in certain of the newer countries in the pre-war era. The working out of several of the natural gas and oil fields in the United States drew attention to the quantities of these useful commodities which had been allowed to run to waste, and an echo of the scare raised was soon heard on this side of the Atlantic, and the proximate exhaustion of our coal supplies foretold. The estimates made, of course, were based on rate of consumption and visible supplies, but had no relation to the point which has been so forcibly impressed upon the country this year, namely, whether we can continue to mine the supplies in an economical manner.

Of the countries which have lately paid more than the usual heed to these questions, Canada is in a somewhat unique position. At the two extremities of her borders—New Brunswick and Nova Scotia in the East, and British Columbia, Alberta and Saskatchewan in the West—the Dominion is blest with productive coal mines. The central regions however, including Quebec, Ontario and Manitoba, possess no coal mines, and have to depend for their fuel on imported supplies. These are in part drawn from the producing provinces, and in part from sources across the United States frontier. The area in which these acute fuel conditions occur is, fortunately for the development of the Dominion, uncommonly well supplied with water resources, and the manner in which these are being developed so as to be complementary to the fuel supply is brought out in an interesting manner in a report just issued by the Dominion Water Power Branch of the Department of the Interior of Canada. This report was prepared for a Special Committee of the Canadian House of Commons on the future fuel supply of that country. No less than 83 per cent. of the total water power developed in the Dominion has been brought into use in the acute fuel area.

As yet Canada has only developed a fraction of her total water power resources, but the production already amounts per head of population to practically four times the power so produced in the United States. In the three areas named above, dependent wholly upon imported coal, over 1,800,000 water h.p. are already in use, though the coal consumed in this district amounts to about 21,000,000 tons per annum. In Ontario 100 per cent. of the total coal consumed comes from the United States, while in Quebec 95 per cent. and in the Manitoba area 72·5 per cent. comes from that country, the balance being due to the Canadian provinces. United States imports into other provinces than these three are insignificant.

As a result of an investigation of various authorities, in the report from which we are quoting, the figure of 10 tons of coal has been taken as required for a per horse-power year on a 33 per cent. load factor, under Canadian conditions, per horse-power actually developed, and 9 tons as an average per horse-power installed, this including spare plant, &c. The water power available in Quebec, Ontario and Manitoba and "Head of Lakes" area, amounts to over 15,000,000 continuous 24-hour horse-power. Working this out on a 50 per cent. load factor the coal equivalent at 10 tons per h.p. year would be about 226,000,000 tons. The coal imports actually amount to less than one-tenth of this amount, while the equivalent of the water power developed is about 18,500,000 tons. It is reckoned that if the use of coal had been developed instead of water power, an additional $146,500,000 per annum would have been expended on imported fuel and freight.

The uses to which coal are put in Canada are approximately as follows:—Railways and bunker coal, 44·2 per cent. of the total consumption; industries and coke making, 28·5 per cent.; electric power plants, 1·5 per cent.; and domestic uses and gas works, 25·8 per cent. The large proportion used on the railways is due to their length compared with the population, in Great Britain only 9·3 per cent. of the total being so consumed. In fact, in rough approximation the two countries may be said to use about the same amounts, though in one case the population is but one-fifth of that in the other. This heavy consumption, the report points out, is a good reason for considering railway electrification in certain areas. In Canada the electric power plants are mainly water-driven, and the coal consumption under this head is very small compared with that of Great Britain. With regard to the proportion of fuel used for domestic purposes the rigorous climate of Canada necessitates effective heating of interiors, which, however, is mostly done in the area with which we are now concerned by means of furnaces using imported anthracite. In this country the proportion of the total is somewhat larger, due to the more extensive use of open firegrates and large use of gas.

In considering the whole question it must be remembered that for house heating anthracite is almost exclusively used in Canada wherever procurable, and all this has to be imported. The imports of this class of coal amounted to 4,912,964 tons in 1920. To offset this to some extent may be placed the electrical energy exported to the United States, which for the 12 months, 1919–1920, amounted to 950 million k.w.h. If 4·7 lb. be taken as an average for central station consumption in Canada, the energy exported would be equivalent to nearly half the imported anthracite.

Owing to the facts that the railroads use soft coal and run through areas where this is cheap, and that the population at present is only sufficient to warrant the consideration of comparatively limited schemes of electrification, it is interesting to consider the development of electrical power for other purposes than railroad use. For the reason given above, household heating can also be excluded. Omitting these two, the water horse-power developed in 1920 was greater (measured in coal equivalent) than the total soft coal consumption in Canada by some 12½ per cent, and there is every prospect of this preponderance being increased in the near future. On the estimated annual saving on coal quoted above, from the national point of view the water power development is considered to be equivalent to a return of 27·5 per cent. on the capital actually invested.

HYGROMETRY.

It does not require a spell of foggy days to remind us of the importance of atmospheric moisture. A slight fall in temperature, especially in the presence of dust and smoke, will lead to a condensation of the invisible moisture as mist, dew, rain or snow. Our comfort, the work in textile factories, the drying of timber and of clothes, and the pitch of our musical instruments, are all influenced by the humidity of the air. Yet even meteorologists have of late little advanced the study of hygrometry, and the discussion of "Hygrometry" by the Physical

Society recently brought out the fact that our common hygrometric instruments, like many others, are defective, and that their theoretical basis remains obscure. Sir Napier Shaw stated that the wet and dry bulb thermometer, used almost everywhere, was useless for temperatures just below freezing and should be discarded; the hair hygrometer was preferable, but it suffered from age and other infirmities. The action of the hair hygrometer depends upon the expansion of the hair by the absorption of moisture. But, the puzzled unscientific man asks, why does that expansion continue when it freezes, and why does a wetted rope of hairy fibre contract?

To approach the problem we have to distinguish between absolute and relative humidity. Of the absolute humidity, the momentary percentage of water vapour in the air, our nerves are very poor judges, as long as we are not near saturation. The absolute moisture can easily be estimated by passing the air through sulphuric acid, calcium chloride or other substances which absorb the moisture; but such instruments are inconvenient. Mr. H. G. Mayo and Professor A. M. Tyndall showed a new portable absorption hygrometer at the meeting above referred to. A brass tube, about 9 in. long, 1 in. diameter, can be closed by plugs; inside is a plunger with perforated bases, which slides up and down when the tube is tilted. The plunger contains phosphorus pentoxide and glass wool, through which the air has to force its way; an oil gauge branched off from the tube indicates the volume change. Concordant results have been obtained with this hygrometer within a temperature range + 17 deg. to — 10 deg. C., but the temperature must not be submitted to sudden fluctuations.

The rate of absorption of hygroscopic substances is not independent of the relative humidity, *i.e.*, the ratio of the elastic force of the aqueous vapour actually in the air to the elastic force of the vapour which it might contain if it were saturated with aqueous vapour at the same temperature. Any organic fibre will absorb or liberate moisture according to its own degree of saturation and that of the atmosphere, and instruments of this type are very old. At the meeting, Mr. F. C. Bayard showed one described by Hooke in his Micrographia of 1667: a piece of oat beard was fastened at one end to a case resembling a lady's watch, and at the other to the pointer moving over a perforated dial. In Saussure's hair hygrometer of 1783 the hair is coiled round a pulley and weighted at the end. Dr. Ezer Griffiths, whose studies at the National Physical Laboratory on behalf of the Food Investigation Board, communicated to the meeting, constitute the most important recent research on the subject, finds that though the hairs, being under slight tension, acquire a set in the course of time and tend to give too high readings, these hygrometers yet work satisfactorily even below freezing-point, provided they be frequently checked, oil vapour (the hair should be free of grease) and dust be kept out, and large temperature fluctuations be avoided. As to their action, Mr. F. J. W. Whipple suggested that the hair cells absorb moisture and that the pressure in them is negative, the liquid in the fibres being in tension, a condition which is also proved by the fact that the sap rises in trees.

The psychrometer or dry and wet-bulb hygrometer is generally ascribed to John Leslie who, in 1813, converted his differential thermometer into a hygrometer by keeping the one bulb dry, and the other wet by means of muslin soaking in water. Considering that in a calm the bulb will soon be surrounded by a stagnant layer of moist air and that on freezing heat will be liberated on the bulb, it is surprising that the ordinary stationary instrument can give fairly correct results—except in dry climates, as in Egypt—and that it is still tolerated.

In the aspiration psychrometer of Assmann a clock-driven fan draws air at a speed of about 5 (now mostly 10) miles per hour up a tube which below forks into two branches containing the two thermometers. Assmann devised his aspiration instruments (thermometers, &c.) for use on balloons, and found that the constant of an instrument would hardly change with the speed, provided a speed of about 2 metres per second was exceeded.

Mr. W. Watson Watt, having experimented in the 7-ft. wind channel of the Royal Aircraft Establishment, stated at the meeting that the constancy still held for speeds from 60 m.p.h. up to 90 m.p.h.; but the experiments would have to be extended as the temperature ranges were small, only varying from 51 deg. to 67 deg. F. (roughly 10 deg. to 20 deg. C.), whilst Assmann's tables cover the range + 30 deg. to — 30 deg. C. Dr. Griffiths observed that in a room at — 3·5 deg. C. the wet bulb moistened with water went down to — 4·4 deg. in 3½ minutes, when the muslin probably froze to the bulb, and then kept steadily about 1 deg. below the dry bulb for hours. But he did not consider this type of hygrometer suitable for cold-storage observations to be taken at distances, and he had also the usually expected difficulties with dew-point instruments.

In the original dew-point hygrometers of Daniell (1827) and Regnault ether is made to evaporate (by the aid of a vacuum or of air bubbled through the ether) in a bulb which is surrounded by a polished metal ring or "thimble"; the dew condenses on the metal and the air temperature is read at that moment. Dr. Griffiths cools a metal disc of copper, *e.g.*, by mounting a brine coil at its back, or presses a steel mirror directly on the cold surface. To determine the moisture in the cold stores on board ship he uses a tube, 8 ft. long, of aluminium, provided with an ether pipe and thimble at the far end, a thermometer scale and mirror next to it, a telescope at the eye end, and small lamps to illuminate the thimble and scale We have referred to other hygrometers of Dr. Griffiths on several occasions. To render such instruments continuously recording is, however, very difficult. Even if there were no time lag in the formation of the dew, and in its re-evaporation with rising temperature, it is not easy to convert the thermocouple indicators into relays to open and to stop the brine flow. Dr. Griffiths therefore tried to make use of the change of electric resistance which is produced when a film of moisture settles on the gap between two platinum mirrors deposited on glass. Owing to the lag mentioned the resistance change was not sharp, however, and when the glass was ground, the curve did not return on itself, probably because the moisture attacked the ground glass.

Two peculiar types of thermal hygrometers have recently come into use. Orme Masson observed in 1904 that a cotton-covered thermometer heated on being exposed to moisture. Professors A. M. Tyndall and A. P. Chattock described a delicate instrument of this kind, designed for the purpose of measuring the humidity in the egg space under sitting hens; information on that point was wanted by the Board of Agriculture in connection with the physics of hen incubation. A brass tube contains two thermo-junctions; one of these is bare, the other, wrapped with cotton (really a piece of cigarette paper), is opposite a hole in the tube, so that it can be exposed to the horizontal projections from one of three cylinders in the middle of which the tube is suspended. By means of a lever the tube can be turned in its tubular guide so that the cotton faces one of the three cylinders, which contain respectively the air or liquid under test, some sulphuric acid, and dry air over phosphorus pentoxide. Dr. Griffiths has constructed more robust instruments, in which resistance thermometers, *i.e.*, two platinum spirals, one covered with cotton, replace the thermo-junctions in columns through which moist or dry air is sent by bellows. With these apparatus a change from a drying to a wetting atmosphere can quickly be made, as in the one just mentioned, and it is found that the drying of the cotton is first rapid for a few seconds and then goes on slowly.

The other thermal instruments, the katharometers or hot wire hygrometers of Dr. G. A. Shakespear, were described by him and by Dr. H. A. Daynes. Two identical fine platinum spirals are stretched in two small cylindrical cavities, about 5 mm. wide, of a copper block; the one cavity is closed and contains the reference gas, *e.g.*, dry air; the other communicates with the gas under test by three small ports, 1 mm. in diameter. The wires are heated by a current and form arms of a Wheatstone bridge. The rate of cooling of the hot wires depends upon the density of the surrounding gas, and in this way a few per cent. of the hydrogen present in air can be estimated. The Cambridge and Paul Instrument Company exhibited a new CO_2 recorder of this style fitted on the lines of their thread recorders. Carbon dioxide and water vapour would affect the instrument in the same sense, but if the air is kept saturated with water vapour in both the cavities, the apparatus records the CO_2. One might think that the diffusion through the very small ports would be very slow; but the curves exhibited proved that the katharometer responds with astonishing rapidity.

The Factory Act of 1901 prescribes the use of ordinary wet and dry-bulb hygrometers for textile works and limits the relative humidity to 80 per cent. at 35 (33) deg. F. dry (wet) bulb when the air will contain 1·9 grains of water per cubic foot, to 88 per cent. at 60 (58) deg. F. and 5·1 grains of moisture, and 90 per cent. at 81 (79) deg. F. and 9·8 grains of moisture, &c. Hard things were said about these hygrometers at the meeting, but as the Act also provides for ventilation the accuracy does not matter much. Mr. W. J. Hall, of the British Research Association for Woollen and Worsted Industries, stated that weavers worked with the air nearly saturated, and that by 4 p.m. thread ends were apt to break, being overladen with moisture, but if the fibre was too dry in the drying house, there was considerable loss by fly waste. He was aware that he could not rely upon his hygrometers, but he was afraid also that Trouton in his absorption studies had experimented with mixed (wool and cotton) fibre when believing to have pure wool; even pure wool, however, seemed to change its absorption power in the course of a year or two.

As regards the theory of the wet and dry bulb two more contributions to the very interesting discussion have to be mentioned. Principal Skinner referred to his experiments confirming Maxwell's formula; the ordinary practice relies on the so-called Glaisher factors. Dr. G. C. Simpson, director of the Meteorological Office, said that he had himself regarded the wet and dry bulb values as more or less accidental. But Dr. W. O. Normand, of Simla, was now approaching the problems from the thermodynamic standpoint by considering the changes as adiabatic, and those considerations seemed to put the theory on a sound basis.

PREVENTABLE RAILWAY ACCIDENTS.

WHILE we do not nowadays hear the absurd clamour which used to be raised before the war when any railway accident occurred, calling for the introduction of all sorts of costly changes in practice, it is well to consider, as information becomes available, what improvements may be possible to ensure greater safety in railway working.

It is well-known, of course, that the majority of the accidents on railways do not happen to passengers, nor are accidents to trains responsible for any great number. While, for instance, in 1920, according to the latest returns, 6 passengers were killed and 684 injured in train accidents, in other accidents due to the movement of vehicles, &c., 115 persons were killed and nearly 2,000 injured. On the other hand, the total casualties to employees classed under accidents in which train movements were not concerned numbered 17,558, while in the class of "other accidents in which the movement of trains, &c., was concerned" the total casualties were 4,608, including the unfortunately heavy roll of 371 fatal cases. On the whole the figures for 1920 show a considerable increase on those in 1919, though at the same time the traffic handled, and the number of employees also increased in the twelve months concerned.

The Inspectors of the Ministry of Transport inquired into 25 train accidents in 1920, and of these it was concluded that seven were due to failure, or insufficiency of, equipment. Of these seven it is stated that two pointed to the need of improved means of "detecting facing points." Two others were attributable to faulty brake maintenance, while other two point to the desirability of more expeditious and reliable means of cutting off electric traction current. Altogether ten accidents were due to enginemen failing to observe or

give effect to danger signals or to regulations. In these cases it is suggested that five accidents would possibly have been prevented by the adoption of automatic train control, the other five being purely cases in which a proper degree of caution would have avoided all trouble. Obedience to, or correct procedure with regard to, regulations, on the part of signalmen would likewise have sufficed to avoid five out of seven accidents, while in the other two track circuiting would have checked the liability to irregular working. The report further lays stress, as a result of the year's work of inquiry, upon the need of firemen and porters being respectively better instructed in footplate and brake coupling duties, and the need for co-operation between signalmen in connection with signal and point lever working. The difficulty of enginemen reading correctly fixed signals when placed outside a number of running roads is also emphasised with a view to this arrangement being avoided.

For the information of those who consider the railways always unwilling to take advice, it may be stated that in 21 of the cases inquired into recommendations were made, of which 16 were acted upon wholly or in part, and 2 are still under consideration.

Of the accidents to companies' servants due to movement of trains and vehicles, but exclusive of train accidents, 26·7 per cent. of the fatal and 65·8 per cent. of the non-fatal are described as due to misadventure, or accidental. The respective figures for want of caution, disregard of rules either on the part of the persons injured, or others, are 69·48, and 30·31, in both cases the preponderance being due to the fault of the person injured. Defective apparatus or systems of working were responsible for less than 4 per cent. in the case of either fatal or non-fatal accidents. Out of 4,597 accidents to servants, Colonel Pringle states that not more than 190 could be said to be due to preventable causes. Of these the more numerous are classified as follows: 33 due to defective engine equipment; 26 to dangerous systems of working on the permanent way, to tow-roping, shunting, &c.; 23 to defective wagon brakes; 18 to defective capstans; 16 to failures of coupling poles, &c.; 15 to want of brake levers on both sides of wagons; another 15 to defective vans and wagons; 14 to insufficiency of clearance of permanent structures, and 13 to ground obstructions at stations, siding, &c. The Chief Inspector states that recommendations have been made, and where practicable action has been taken with good effect, under all heads. The great bulk of the casualties, the report concludes, characterised as due to accident or want of caution, &c. (95·9 per cent. of the total) can only be avoided by education of the employees in the direction of safety working, along which lines it is well known that many of the railways are already progressing.

The last remark, of course, applies also to the 17,558 non-movement accidents to employees, 95 per cent. of which it is stated are ordinary industrial accidents, as, for instance, accidents in loading and so on. Of these it is stated that not more than 1·4 per cent. had been attributed to defect in apparatus, want of safeguards, &c. While the total number may appear to some higher than is at all desirable, it has to be remembered that under existing regulations many very trivial mishaps are classed as accidents and go to swell the total very considerably.

NOTES.

Domestic Labour-Saving Devices.

Changed economic conditions have emphasised the need for domestic labour-saving devices. In fact, the situation here is approximating to that which has long prevailed in America, where the difficulty of securing satisfactory domestic service has largely contributed to the popularity of labour-saving devices in the American home. Of late many women here have complained of the little that has been done to lighten the task of the housekeeper, a condition which has at times been attributed to the callousness of men. Women are now to have the opportunity of showing what they themselves can do in the way of suggesting improvements, since the Women's Engineering Society have organised a domestic labour-saving competition, which will be open to all women irrespective of whether they belong to the society or not. The exhibits will be divided into three sections: (*a*) Engineering devices suitable for mechanical, electrical and automobile work, &c.; (*b*) structural improvements; (*c*) miscellaneous domestic saving appliances. An entrance fee of 2*s.* 6*d.* will be charged for each entry, and only working models or working drawings will receive consideration. One of the chief points considered in making awards will be the economy with which the idea can be carried out. If sufficient entries are received, an exhibition of them will be held early next summer. Full particulars of the competition, which is open to women only, can be obtained from the Women's Engineering Society, 26, George-street, Hanover-square, London, W. 1.

Special Alloy Steel Research, United States.

A report issued by the Federal Bureau of Mines states that the United States own the largest known deposits of molybdenum ores, but are relatively poor in high-grade deposits of some other important elements used in alloy steels. Whilst nickel, chromium and vanadium are the main elements in present-day alloy steels, the States have very little nickel; they have some chromium, but mostly in relatively low-grade ores, and only small deposits of vanadium. It is, therefore, of the utmost importance to know to what extent molybdenum can replace any of these elements. According to tests made by H. C. Chandler and C. H. Willis, molybdenum, as an alloying material, ranks with nickel, chromium and vanadium in the manufacture of steel of high quality. A comprehensive series of molybdenum steels, with other steels for comparison, has been made in the electric furnace laboratory of the department of chemistry at Cornell University, and the steels made have been rolled at the Halcomb Steel Company's plant. Test bars have been machined, heat-treated, and subjected to tensile and fatigue tests at the same university. These tests are not yet completed; when they are, the results, it is said, will add materially to the knowledge of the properties of molybdenum steels. Further, in order to study the effect of cerium on steel and non-ferrous alloys, an agreement has been entered into between the Bureau of Mines and the Welsbach Company, the latter supplying cerium compounds which are a by-product of the gas-mantle industry. The work on cerium steels is being carried out concurrently with that on molybdenum steels, and in a similar manner. It has been established that cerium can exert a desulphurising action. The preparation of cerium steels is, however, surrounded with difficulties, and no final conclusion can as yet be drawn concerning them. Other, co-operative work of the Bureau of Mines with the Navy has been completed, the report adds, and considerable progress has been made in the investigations on both molybdenum and cerium steels. In the past fiscal year the work done on the preparation of zirconium and other steels for the Navy was mainly analytical, and the results showed the advisability of some changes in methods of analysis for zirconium.

The Problem of Grey Iron Castings.

The expediency of reading metallurgical papers before engineering institutions is one which we have always welcomed. A proceeding in the opposite direction, namely, the reading before our metallurgical institutes of papers by engineers and users of material would be most probably productive of excellent results. In the first category is a paper having the above title, by Mr. H. J. Young, read on the 13th inst. before the Institute of Marine Engineers, Incorporated. In his opening statements the author is decidedly pessimistic and makes a dead-set at ironfounding, which he calls "a trade wonderful in its empirical experience and behind all other trades in its scientific knowledge." Further on, when referring to cupola-melted metal and the control of the cupola, he states that our knowledge of cupola practice is insufficient to enable us to predict that what we require cannot be obtained from that apparatus. He also points out the numerous and extensive variations which exist in the composition of numerous different deliveries of pig-iron used in the foundry. "Nevertheless, castings of nearly standard composition can be produced even under dubious conditions of cupola control to which, for lack of measuring instruments, we are still subjected," and the author gives examples to illustrate his statements. One example is that of a cylinder liner, the metal of which "was evolved gradually over a number of years of observation of the behaviour of various grades of cast iron; heavy and thick as were these castings, the test bars cut out of them gave nearly the same tests as the test bars cast on them, namely, about 12 tons tensile and 2,300 lb. transverse, on Admiralty square bars." In view of these statements by the author, and the evidence he brings to bear upon the control of the cupola, the possibility of keeping the phosphorus down, the control of silicon "which has assisted ironfounders the world over," we do not think it can really be said that ironfounding is quite as backward as he appears to make out. He himself has tabulated some thousands of results for guidance; other makers have most certainly done the same. The papers which have been read from time to time before the Iron and Steel Institute afford a proof that the subject is one which has occupied, and is still occupying, the mind of metallurgists generally. As is the case with every branch of trade, much has yet to be learned in ironfounding, and facilities in this respect will be offered by the British Cast Iron Research Association which, we are informed, has recently opened offices in Birmingham.

Fires in Ships' Bunkers.

Of the 242 cases of fires occurring on British ships during the year ended July 30, 1920, nearly one-third, or 74 to be exact, occurred in the bunkers. In almost one-half of these bunker fires the cause has been conclusively shown to be due to the so-called spontaneous combustion of the coal, and the circumstances attending practically all of the other cases leave little room for doubt that the trouble was due to the same phenomenon. More recently, further interest in the matter has been aroused by the occurrence of serious bunker fires in the mail steamers Saxon and Port Augusta, and in view of its extreme importance Dr. J. T. Milton, until recently chief engineer-surveyor to Lloyd's Register, has submitted a report on the subject to the committee of that society. Dr. Milton has examined all available evidence, including an analysis of the 74 cases above referred to by the engineer surveyor-in-chief of the Board of Trade, and he considers that the conclusions given in a report to the Committee of Lloyd's Register in 1912, do not require any modifications or additions. The main conclusions of the 1912 report were to the effect that the heating of coal, and the consequent risk of spontaneous combustion, is caused by the absorption of oxygen from the air and that this absorption is greater at high temperatures than at low. To minimise the absorption of oxygen by the coal in reserve bunkers, or in any bunker in which men are not actually working, the lower doors should be kept tightly closed so as to prevent a current of air from passing through the bunker. Any parts of a bunker likely to be at a temperature higher than the normal, the report continued, should be stowed with large coal, which should be worked out as soon as possible, as also should the small coal which accumulates under shoots, &c. Another important point to which attention was called was that the danger of spontaneous combustion increases with the length of time the coal remains in the ship, so that any coal left in a bunker when a fresh supply has to be taken in should be trimmed into such a position that it will be used on the next voyage. No risk, it was pointed out, arose from coal being wet when taken on board, and small coal, when known to be of a fiery nature, might with advantage be damped when filling the bunkers. Finally it was mentioned, that although some kinds of coal had been proved to be more liable to spontaneous heating and combustion than others, the trouble might occur with any coal, not excepting anthracite. It is obviously of the utmost importance that engineers of vessels should keep these points in mind in order to minimise the risk of fire at sea.

INDUSTRIAL NOTES.

THE Paris Association of owners of metallurgical works, mines, and allied industries have recently published the results of an *étude* they have carried out on the 8-hour day in metallurgical and engineering works, based upon information received from a number of different firms established throughout France. They have found that the consequences of the application of the 8-hour day in the said works, from the point of view of increased labour charges for an equal output, vary according to process, whether continuous or otherwise. In regard to the continuous process, it should be noted that technical improvements to furnaces and accessory plant were made, to meet industrial needs, quite apart from the 8-hour day. The shorter working day, in a general way, has had no effect upon the output of metallurgical works, since the output of such works depends mainly upon the time the transforming operations last and upon the working of the apparatus; on the other hand, it has led to the increase in the number of "metallurgists," of "machinery workers" and of "auxiliary services men." The "metallurgists" are the men forming the shifts directly entrusted with manufacture. In regard to these, it was anticipated when the three-shift system was introduced—a system which made no change in the frequency of the operations—that it would be possible to reduce the number of men in a shift, each man doing the same effective work as formerly; the men, however, did not agree, and the three-shift system was accepted by them only following an increase in the number of men to the order of 30 per cent. to 50 per cent. In modern establishments, the "machinery workers" are gradually taking the place of those "metallurgists" who are specially robust, and the machinery having to be constantly attended, the number of such workers has been increased by about 50 per cent. The "auxiliary services men," *i.e.*, those employed on the tracks, storehouses, the labourers, men on maintenance, &c., have also been increased in the same proportion. Briefly, it may be said that for an equal daily output, the number of men employed is now increased by from 45 per cent. to 50 per cent., and the increase is the greater the more modern are the works, and the greater use they make of mechanical apparatus. Since under the regulations of the 8-hour law each workman has to receive the same wage as formerly, labour charges for the same production have increased by about 45 per cent. to 50 per cent.

In the matter of the industries in which there is no continuous process, and in those in which engineering work is carried out, where, in both cases, remuneration is based on output, it has been found that the 8-hour day scheme has had for effect to increase the hourly wage earned by roughly 25 per cent., the daily wage remaining practically as formerly. The increase in the hourly wage earned is due both to an increase of about 20 per cent. in the wage rates, and to a rather more strict observance of shop rules. Formerly the men worked during 9 hours and 20 minutes; now they work during 7 hours and 40 minutes. The man who formerly manufactured 100 pieces, now manufactures only $\frac{100 \times 7{\cdot}66}{9{\cdot}33} = 82$ approximately. In order to obtain the same output as formerly, it is necessary therefore to increase by about 18 per cent. the number of men employed and the total cost of labour.

An increase of the same order takes place in every phase of manufacture, from the raw material right up to the finished product as this is delivered for use or for consumption, there being for each operation a higher cost than before the 8-hour day was established by law. The various industries react one upon the other; for example, the disorganisation of transports and the increase in railway goods tariffs, partly due to the 8-hour day, have greatly contributed to a further increase in cost of metallurgical and mechanical products. The 8-hour day has made for smaller supplies in certain raw materials, leading to an increase in the cost of these even before any transformation operation has taken place upon them. Other consequences of the same measure have also come into play. Not only every product, but also every necessary of life has increased in cost by reason of the same causes and the workman, whilst earning the same daily wage for 8 hours as he did formerly for 10, finds his purchasing power diminished, notwithstanding the care taken by legislation to maintain his wage at the former level.

Speaking last week at the fifty-fourth annual general meeting of Messrs. Vickers, Limited, Mr. Douglas Vickers, M.P., the chairman, said the fall in freights had seriously embarrassed all shipowners and had brought some to bankruptcy or to the verge of it. This had, of course, reflected on ship construction. Orders had been suspended or cancelled, or in some cases completed only on modified terms involving loss to the shipbuilder. In other engineering trades also high wages and low output at home, as compared with the low wages and high output in foreign countries with depreciated currency, had made it most difficult to secure orders. The price of coal still remained at far too high a level. It appeared that the field for armament work would be very much reduced, and that it would be impossible for the company to retain more than a small proportion of its large expert staff, or to continue to spend large sums, as of old, on experiment and development in this connection. Measures had, therefore, been taken to effect at once very large staff reductions, and at the same time a part of the staff retained would be removed from London to Sheffield and Barrow, where it was thought they would be more easily employed in directions other than armament work. The company was parting with very great regret with many of their old employees, who had rendered very good service in the past, but no other course was possible.

The Central Railway Wages Board agreed last week to the reduction of the railwaymen's wages by 4*s.* per week, following the fall in the cost of living, wages, under the sliding scale agreement, falling at the rate of 1*s.* for every five points. The last change in railwaymen's wages was made last July, when the index figure stood at 119; as stated in our last issue, it is now 99, or 20 points less. The present reduction will take effect from January 1.

The British Commercial Secretary at Berlin, in a recent despatch to the Department of Overseas Trade, reproduces certain figures published in the German press illustrating the rise in wages and salaries in the State Railway Service, as compared with the pre-war period. The wages of manual workers show the greatest increase, being approximately from 12 to 15 times the peace-time rates. Engine-drivers, for example, were receiving about 11¾ times the corresponding rate for August 1, 1914, stokers 13¾ times, guards 13½ times, signalmen 14¾ times. The remuneration of non-manual workers had advanced more slowly. Among executive officers, chief inspectors were in receipt of 7½ times the pre-war salary, inspectors and chief clerks 7 times, clerks 7¼ times. The salaries of administrative officials were from 6 to 7 times the 1914 rate.

The Acting High Commissioner in London for the Commonwealth of Australia states that the New South Wales Government Statistician has issued a report showing that notwithstanding the difficulties of recent years, industrial business in the State is expanding. The number of employees for 1919-20 showed an increase of 16,863 over the previous year. The value of the output increased from 104,803,081*l.* to 123,213,480*l.* The difference of 18,410,399*l.* is accounted for by an increase of 13,451,045*l.* in cost of raw material, and an increase of 2,714,921 in the value of machinery, plus the increase of wages.

An increase of 25 per cent. in the volume of iron and steel exports from Germany in September, when compared with the average monthly exports for the preceding four months, is shown in a cabled report made to the Department of Commerce, by Commercial Attaché C. E. Herring, Berlin, says *The Iron Age*, New York. Exports of rolled zinc showed the remarkable increase of 90 per cent., whilst copper and copper goods increased 16 per cent. and coal 35 per cent. Exports of machinery showed a decrease of 12 per cent. The improvement in the German iron and steel industry, however, is partially offset by labour unrest. Mr. Herring refers to a strike declared on November 14, by 60,000 Dusseldorf metal workers, who demanded an increase in wages. This dispute has been settled by the raising of the average wage level 15 per cent. and full work was resumed on December 4. The total production in the metal trade was apparently reduced by 2 per cent. during the period of the strike. Estimated figures for Germany's foreign trade during September and October show that both imports and exports are increasing.

If proof were needed that Germany is working hard, adds our American contemporary it would be afforded by the heavy buying of American copper. This has reached proportions never equalled. For the ten months ended with October, exports of refined copper to Germany have been 39·50 per cent. of the total and more than the combined exports to France, Great Britain and Japan. Out of total exports of 468,215,221 lb. Germany has taken 184,739,354 lb., whilst 177,852,061 lb. went to the three other countries mentioned. If the American exports to Holland of nearly 21,000,000lb. are in part for German consumption, then Germany's share of the total exceeds 40 per cent. In 1913, exports of copper to Germany were larger than to-day, but the percentage then was only one-third of the total. The larger percentage now, in spite of the smaller actual total, is impressive, proving the high state of operations in the one country when business in the rest of the world is depressed. In 1913, every effort was being made in Germany to gather up stocks in preparation for war; to-day metal purchases are made in spite of the almost vanishing purchasing power of the mark.

An abstract of an article by Dr. Macnamara, Minister of Labour, published in *The Glasgow Herald*, forms a very fitting ending to these notes for the current year. Dr. Macnamara, after recording the promise of an improvement in the business situation of this country in the early spring of the present year, mentions "the disastrous dispute in the coal industry which came down like a black fog." He also refers to the steps taken by municipal authorities and by Government to find remedies and palliatives for unemployment. He adds that during recent months there has been a growing disposition on the part of employers to get their workpeople together, put the whole of the cards upon the table and discuss the situation frankly and freely with them. Where this has been done, instead of strife, further dislocation and further misery, accommodation has been reached whereby endeavour has been made to narrow and, if possible, to wipe out altogether the gap between manufacturing costs and selling prices. Both parties have shown themselves to an altogether praiseworthy extent ready and willing to shoulder their due share of the reductions—reductions in profit, in dividends, in overhead charges and in wage—necessary to get prices down to a figure which will attract the buyer. He thinks the fact that the cost of production could be just as directly reduced by increased output as by direct "cuts" in expenditure has not been sufficiently realised. The Government, he further states, profoundly appreciated that industry was to-day handicapped by the burden of taxation. That was a direct heritage of the war. But it was up to the Government, by the most ruthless reduction in all non-vital services, to do everything within its power to reduce the present financial burdens upon industrial operations, burdens which so seriously restricted industrial expansion. The experiences of 1921, he says, in conclusion, lead him to respect more than ever the solid good sense of the British people, employers and employed, and the spirit of genuine comradeship which is more and more weaving confidence and goodwill into their relationships.

THE EXAMINATIONS OF THE ROYAL INSTITUTE OF BRITISH ARCHITECTS.—The Royal Institute of British Architects are publishing periodically the questions set at past intermediate and final (or special) examinations. Those questions set at the examinations held in June, 1921, are now ready, and copies may be obtained at the Royal Institute, price 1*s.* 6*d.* exclusive of postage. Past questions are always of great value to candidates who intend sitting for examinations, as they are excellent guides as to the lines upon which candidates should proceed in preparing themselves. The Institute has also published a short pamphlet containing advice to candidates for the Royal Institute examinations, together with a list of books recommended to those who are studying architecture. This pamphlet contains some valuable information, and it may be obtained free on application to the Royal Institute of British Architects, 9, Conduit-street, London, W. 1.

WOOLWICH ARSENAL: ENCOURAGEMENT OF APPRENTICES.—Most engineers have many pleasant recollections of the days of their apprenticeship, but it is not often that they show, in a tangible way, their appreciation of the trouble that was taken with them, and the facilities afforded to give them a thorough training. Mr. J. S. Broughton, of Denver, Colorado, U.S.A., who was a Trade Lad (the equivalent of apprentice) in the Royal Arsenal from 1875 to 1882, has visited Woolwich this month to found a special scholarship in memory of his father and as a stimulus to trade lads. His desire is to enable the most meritorious lads to be fully equipped to enter college and take an engineering degree. He has himself given a large sum of money to be invested, and is also desirous that other successful ex-trade lads should give generously to make the fund sufficiently large to remove all financial embarrassment in particularly deserving cases. The Chief Superintendent of Ordnance Factories, Mr. J. Bowden, O.B.E., M.I.Mech.E., arranged a special prize giving for the Arsenal lads, which took place at the Woolwich Polytechnic. Mr. Bowden himself presented the prizes, showing by his remarks individually to the recipients, and collectively in his address, that he had the welfare of the apprentice at heart and would do all he could to further their interests. Mr. Broughton, on being asked to speak, emphasised the value of a thorough training, spoke words of encouragement to the lads, gave a spirited account of his early struggle in life, and told the lads that they had excellent opportunities of obtaining a splendid training in the Arsenal. We are asked to request other successful engineers who were trained in Woolwich, and who would be prepared to help promote so worthy an object, to communicate direct with the Chief Superintendent of Ordnance Factories, Woolwich, who will gladly furnish further particulars of the scheme.

FOUNDRY COSTS AND ESTABLISHMENT CHARGES.*

By Daniel Adamson, M.I.Mech.E., Member.

The correct ascertainment of costs is acknowledged to be an important part of manufacturing, and particularly of engineering, and in no part of engineering practice is this question of greater interest than in a foundry. In a recent address on "Foundry Problems," Lord Weir said that the advances in wages and prices of raw materials during recent years, by accentuating the necessity for increased and more economical production, had "elevated the subject of foundry costs to a position of prime importance" (see ENGINEERING, November 19, 1920, pages 687 to 689.)

In other operations of engineering the raw material is provided in some finished form, so that it is sufficient to base the cost of the material used upon the market price at which it can be purchased, but in foundries the material has to be converted from a more elementary condition into a usable form with the help of fuel, labour and power, and the cost of this conversion has a varying effect upon the cost of the finished article according to the amount of material required per piece. His object now was to endeavour to arrive at a reliable method of estimating the cost of the many varieties of castings in green sand, dry sand or loam, that are produced in the foundry attached to a general engineering business.

When a proposal to introduce a scheme of "payment by results" or "bonus on output" is under consideration, it is essential to have a proper knowledge of current costs to enable reliable calculations to be made as to the probable effect of such schemes upon their ultimate success. On inquiry amongst his friends, he finds that a very common method is to divide the output of the foundry into light, medium and heavy castings, without any definite law to guide those responsible for making the division.

It is becoming more usual to take note of the cost of skilled labour employed in making the mould, and as the casting is more intricate, or larger, more moulder's time will be booked to the job. It might appear, therefore, that it would be sufficient to take the value of the skilled labour booked to the job as a basis for the costing operations, but this is not a fair division as between the simpler castings and others of more elaborate design, taking considerably more labour to mould, although, perhaps, of the same weight when cast.

If the skilled labour were to be taken as the basis for the calculations of cost, then the intricate casting would carry more than its due share of establishment charges, because part of these charges is involved in handling raw material, and in melting the same in the cupola, with consequent expenditure of fuel and power. It follows, therefore, that a plain casting would, under the circumstances suggested, come out cheaper than was justified, because the labour cost would be low, while the amount of metal used would be equal to the more expensive casting.

The division of the indirect charges as between the molten metal and the workmanship expended on the mould, is a matter to be estimated for each particular establishment. The indirect charges should be ascertained at regular intervals, say every four weeks, and can then be allocated somewhat as follows :—

Unallocated labour : 25 per cent. of this item to be charged to "metal" and 75 per cent. to workmanship account.

Power : 50 per cent. to metal and 50 per cent. to workmanship.

Light : 20 per cent. to metal and 80 per cent. to workmanship.

Foremen's wages : 20 per cent. to metal and 80 per cent. to workmanship.

Clerical charges (including management) : 35 per cent. to metal and 65 per cent. to workmanship.

Office expenses : 25 per cent. to metal and 75 per cent. to workmanship.

Maintenance of buildings, machinery and plant, mill stores and sundries : 25 per cent. to metal and 75 per cent. to workmanship.

Depreciation and obsolescence : 25 per cent. to metal and 75 per cent. to workmanship.

Bank charges : 50 per cent. to metal and 50 per cent. to workmanship.

Rates, taxes and insurance : 15 per cent. to metal and 85 per cent. to workmanship.

When the amounts of the specified items are ascertained over a given period of, say, four weeks, they can be converted into percentages of the totals expended during the period for materials and direct labour respectively, and for the purpose of ascertaining the cost of a particular casting made during that period, the ascertained percentages would be added to the net cost of materials and workmanship respectively, and, in normal times, a further sum to cover contingencies and profit.

The net cost of materials would include the value of everything charged into the cupola such as pig-iron, scrap, coke, limestone. The net cost of workmanship should include as much time as can be booked directly to the job, particularly moulders' and coremakers', also moulding machine time and in some foundries, dressers' time also. To make the suggestion clearer, the following example is worked out using imaginary figures for purposes of illustration only.

The method here suggested would appear to be as arbitrary and empirical as the more common method of dividing castings into light, medium and heavy, already criticised, but as the respective items are dealt with individually, it is easier to assess them correctly or in the event of errors, it may be expected that these will mutually cancel out. From time to time these arbitrary percentages can be overhauled and adjusted by experience, more readily than the less reasoned method.

Typical Example of Working and Costing of Foundry for a Period of Four Weeks.

Castings Produced, 115 Tons.

Indirect Charges (Distributed as Indicated).

—		To Metal.		To Moulding.	
	£	per cent.	£	per cent.	£
Unallocated labour	320	25	80	75	240
Foremen's wages	60	20	12	80	48
Clerical charges and management	40	35	14	65	26
Power	8	50	4	50	4
Light	4	20	1	80	3
Mill Stores and maintenance ..	20	25	5	75	15
Office expenses	8	25	2	75	6
Depreciation and obsolescence ..	40	25	10	75	30
Bank charges	8	50	4	50	4
Rates, taxes and insurance ..	20	15	3	85	17
	528		135		393

Materials Used.

	£	s.	d.
Pig-iron—55 tons at 7*l.* 10*s.* (average of mixing)	414	0	0
Scrap-iron—60 tons at 6*l.* 5*s.* (current price)	375	0	0
Cupola losses—8 tons at 7*l.* (estimated) ..	56	0	0
Coke—25 tons at 5*l.*	100	0	0
Carriage, cartage	70	0	0
	1,015	0	0
Add proportion of indirect charges as above	135	0	0
	1,150	0	0

∴ Cost of metal for 115 tons of good castings produced equals 10*l.* per ton for the period.

REMARKS.—If wasters are made, the weight of castings produced is diminished, and so the cost of metal in the good castings in increased for the period.

The weights of "wasters," "gates," and "risers," &c., put back into the cupola should be recorded as a check on the amount of coke used per ton of hot metal, but must not be included in the materials booked for the purpose of costing, because they have already been accounted for when first charged to the cupola.

Direct Labour.

	£	s.	d.
Moulders	680	0	0
Coremakers	72	0	0
Dressers	100	0	0
Total for four weeks	852	0	0
Proportion of indirect charges as above	393	0	0

∴ Percentage to be added to cost of labour directly charged works out at $\frac{393 \times 100}{852} = 46$ per cent. for the period.

REMARKS.—If "wasters" are made, the labour involved must either be charged to unallocated labour and so increase the indirect charges for the period, or be charged direct and so increase the cost of the particular job.

∴ The cost of any casting, or set of similar castings, weighing say, 10 cwt., and on which, say, 4*l.* worth of skilled labour has been booked, made during the period would be :—

	£	s.	d.
Direct labour, say	4	0	0
Indirect charges on ditto, 46 per cent. ..	1	17	0
Metal, say 10 cwt. at 10*s.*	5	0	0
Total cost of casting	10	17	0

Or 21*l.* 14*s.* per ton.

Since preparing these remarks, he had read a paper presented to the American Society of Mechanical Engineers, by Professor Bird, of the Worcester Polytechnic Institute, entitled "A Foundry Costing and Accounting System," in which it is suggested that the most important items for costing purposes are :—

1. Moulding labour.
2. Core-making labour.
3. Weight of castings produced.

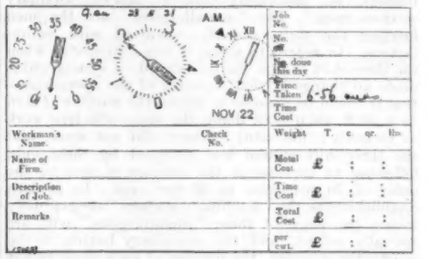
It is stated, for the particular foundry referred to, that it was found necessary, in 1918, to add 81 per cent. to moulding labour to cover supplies and expenses, and 30 per cent. to core-making labour to cover materials for this part of the work. The figures given in the paper (A.S.M.E. Transactions, 1918, page 67) may be summarised as follows :—

Cost of metal ; 75 per cent. of the weight of the castings produced was taken as representing the pig-iron and 37½ per cent. as the scrap iron used, thus apparently allowing 12½ per cent. of net production for losses. The average price of the pig-iron and scrap is taken as 2·30 dols. per 100 lb., or 10*l.* 14*s.* per ton of finished castings. The cost of melting was found to be 30 cents per 100 lb., or 28*s.* per ton. Moulding labour 1·50 dols. per 100 lb., or 6*l.* 17*s.* per ton. Expenses and supplies at 81 per cent. on moulding labour, 1·20 dols. per 100 lb., or 5*l.* 10*s.* per ton. Core-making labour 38 cents per 100 lb., or 1*l.* 18*s.* per ton. Core-making materials at 30 per cent. of the core-making labour, say, 12 cents per 100 lb., or 11*s.* 6*d.* per ton. The total establishment charges are, therefore, 1*l.* 8*s.* plus 5*l.* 10*s.* plus 11*s.* 6*d.*, or 7*l.* 9*s.* 6*d.* per ton. The direct labour is, therefore, 6*l.* 17*s.* plus 1*l.* 18*s.*, or 8*l.* 15*s.* per ton. The average pay per moulder per day was 4 dols., and the production per moulder per day 275 lb.

In the discussion on this paper the author of it was strongly criticised because no notice was taken of the cost of cleaning castings, and no attempt was made to distribute equitably the cost of building repairs, power, light, heat, water, depreciation, taxes, insurance, supplies, delivery and administration, all being lumped together and treated as a percentage on moulding labour only. It is of interest, however, to try to compare these American figures with those shown in the example taken above.

In the latter indirect charges are 4*l.* 12*s.* per ton against 7*l.* 9*s.* 6*d.* in the American example, the direct labour 7*l.* 10*s.* per ton against 8*l.* 15*s.*, and for the material used 9*l.* per ton against 10*l.* 14*s.*; the total cost in my example is 21*l.* 14*s.* per ton and in the American example 26*l.* 18*s.* 6*d.* The indirect charges are 62 per cent. of the direct labour, while the American example shows the indirect charges are 85 per cent. of the direct labour.

In arriving at the cost of the skilled labour booked directly to the job, and upon which the calculations of cost are to be based, attention should be given to the accuracy of the records made, and the most reliable method appears to be that in which job tickets are issued by the foreman to the workman, who, in turn, stamps these in a time clock at the beginning and end of his time on the order. A typical example of a suitable ticket is shown herewith :—



By using the clock in this manner remarkable discrepancies in previous records were discovered, and the conclusion reached that the usual methods of booking time, whether dependent upon the observation of the foreman, or a clerk, or upon the memory or imagination of the workman, are quite illusory and so unreliable as to be almost useless. While the job ticket system is of great value in other departments of engineering it is particularly advantageous in a foundry where it acts also as a check upon the quantity of bad castings made.

The question of a suggested period of four weeks has been mentioned, and it is well worth the consideration of members whether the system adopted by Messrs. Hans Renold, Limited, should not be more generally applied to engineering establishments, that is, to divide the year into 13 periods, each of four weeks, instead of as at present into calendar months, as arranged in the table opposite. If the calendar month is adopted, it means that in every three months there are two periods of four weeks and one of five weeks which make it impossible to distribute the costs equitably for the work produced during the period, while to wait for 13 or 26 weeks to elapse before making this distribution introduces an element of delay and uncertainty that is best avoided in the interests of the correct solution of the problem.

It is possible to arrange the internal accounts of an establishment on this basis, but a difficulty at once presents itself when external invoices, either inwards or outwards, are dealt with, and in his opinion, it would be very much to the advantage of the engineering and allied trades (which are largely interdependent) if a general understanding could be come to for the adoption of the four weeks accountancy period, 13 to the year. This would tend to produce more accurate cost-keeping results.

In referring to the cost of direct labour, mention was made of the time occupied by moulding machines on a particular job, and it might be as well to explain here what was referred to. The whole intention of installing machinery to do what has previously been done by manual labour, is to reduce the time occupied by the workman, or to simplify the operation so that less expensive labour can obtain the desired result. The effect upon the cost system is the same in either case, in that the total cost of the direct labour is considerably reduced. If, as used to be the case, the direct labour is the sole basis for the allocation of indirect charges, it means that the installation of an expensive machine, by reducing the direct labour cost, reduces the share of the establishment charges borne by the work done, with the result that work can be going through the shops showing a very low labour cost and accordingly carrying a very small proportion of the establishment charges, and yet, at the same time, the installation of one or more expensive machines has sent up the real indirect costs of the establishment by calling for more ground space, more power, more light, more crane capacity per man employed, and it would only require a few years of development in this direction to affect the profit and loss account adversely.

It is therefore essential in the interests of sound finance, when considering a machine of any kind to estimate carefully the extra cost involved in depreciation, wear and tear, tool room equipment, and all the miscellaneous indirect charges of a modern establishment, and so ensure that the work done on the new machine is properly charged for.

The output obtained from a jolt ramming machine is from four to ten times what can be done on similar repetition work by journeymen moulders working in

* Notes introducing a discussion at the meeting of the Manchester Association of Engineers, on Friday, November 25, 1921.

HANS RENOLD, LIMITED, FISCAL PERIOD CALENDAR 1921–22.

Meetings.	Period.	1. July.	2. Aug.	3. Aug.–Sept.	4. Sept.–Oct.	5. Oct.–Nov.	6. Nov.–Dec.	7. Dec.–Jan.	8. Jan.–Feb.	9. Feb.–Mar.	10. Mar.–Apr.	11. Apr.–May.	12. May–June.	13. June–July.
Works. Stocks. Sales Shop Stewards (without management). Drawing Office	Monday ..	4	1	29	26	24	21	19	16	13	13	10	8	5
	Tuesday ..	5	2	30	27	25	22	20	17	14	14	11	9	6
	Wednesday	6	3	31	28	26	23	21	18	15	15	12	10	7
	Thursday	7	4	Spt. 1	29	27	24	22	19	16	16	13	11	8
Reward	Friday ..	8	5	2	30	28	25	23	20	17	17	14	12	9
	Saturday..	9	6	3	Oct. 1	29	26	24	21	18	18	15	13	10
	Sunday ..	10	7	4	2	30	27	25	22	19	19	16	14	11
	Monday ..	11	8	5	3	31	28	26	23	20	20	17	15	12
Works. Sales. Superintendents. Senior Board. Financial. Drawing Office	Tuesday ..	12	9	6	4	Nov.1	29	27	24	21	21	18	16	13
	Wednesday	13	10	7	5	2	30	28	25	22	22	19	17	14
	Thursday	14	11	8	6	3	Dec.1	29	26	23	23	20	18	15
Reward. Shop Stewards (with management)	Friday ..	15	12	9	7	4	2	30	27	24	24	21	19	16
	Saturday..	16	13	10	8	5	3	31	28	25	25	22	20	17
	Sunday ..	17	14	11	9	6	4	Jan. 1	29	26	26	23	21	18
Profit-sharing ..	Monday ..	18	15	12	10	7	5	2	30	27	27	24	22	19
Works. Stocks. Sales. Canteen. Drawing Office	Tuesday ..	19	16	13	11	8	6	3	31	28	28	25	23	20
	Wednesday	20	17	14	12	9	7	4	Feb.1	Mar.1	29	26	24	21
Education	Thursday	21	18	15	13	10	8	5	2	2	30	27	25	22
Reward	Friday ..	22	19	16	14	11	9	6	3	3	31	28	26	23
	Saturday..	23	20	17	15	12	10	7	4	4	Apr.1	29	27	24
	Sunday ..	24	21	18	16	13	11	8	5	5	2	30	28	25
	Monday ..	25	22	19	17	14	12	9	6	6	3	May1	29	26
Works. Sales .. Board. Drawing Office	Tuesday ..	26	23	20	18	15	13	10	7	7	4	2	30	27
	Wednesday	27	24	21	19	16	14	11	8	8	5	3	31	28
	Thursday	28	25	22	20	17	15	12	9	9	6	4	June1	29
Reward	Friday ..	29	26	23	21	18	16	13	10	10	7	5	2	30
	Saturday..	30	27	24	22	19	17	14	11	11	8	6	3	Jly. 1
	Sunday ..	31	28	25	23	20	18	15	12	12	9	7	4	2

the old way on loose patterns. If one machine is installed which gives four times the amount of output for the same direct labour cost it means that the net labour cost is divided by four, and unless the cost-charging methods are modified accordingly there will only be one-quarter of the previous amount contributed towards establishment charges. To obviate this it is necessary that the machine be charged at an hourly rate to make up this deficiency, otherwise the other work in the foundry still being done by the old fashioned method will be carrying more than its due share of expenses.

He had been favoured with the figures of working costs for a period of six months ending December 31, 1920, of an installation of eight jolt rammers, with a 500 cub. ft. per minute air compressor, supplying also seven air hoists, five riddles and a sand blast plant dealing with 20 tons of castings per day, and he believes that these will be of value to members. The eight moulding machines were as follows :—

	Size. Lb.	Power. H.P.
No. 1	300	0·84
No. 2	800	1·4
No. 2	1,120	1·67
No. 1	1,120	1·9
No. 2	1,500	2·24

The average cost of running these machines, allowing 10 per cent. for lost time was found to be 1*s.* 3*d.* per horse-power hour, made up as follows :—

	d.
Maintenance	4½
Power (steam-driven compressor) ...	4
Depreciation at 10 per cent. per annum...	3½
Interest on capital at 7 per cent. per annum	3
Total, per horse-power hour ...	1*s.* 3*d.*

NOTE.—A firm of engineers and ironfounders engaged in the manufacture of electrically-driven air compressors informed him that a reasonable allowance for power would be 1½ kw. per machine, or say 3*d.* per hour.

At 1*s.* 3*d.* per horse-power hour the cost of running the eight machines mentioned varies from 1*s.* to 2*s.* 10*d.* per hour, and as the wages of a moulder and helper are about 3*s.* 6*d.* per hour, it pays to adopt moulding machines on suitable work when the increased output mentioned earlier can be obtained.

If the 10 cwt. of castings, in the example worked out above, were made (by piecework) on a moulding machine in one-eighth of the time, the men could double their daywork earnings, and the reduced cost would be as follows :—

	£	*s.*	*d.*
Direct labour, including unskilled help, say	1	0	0
Piecework bonus, say	1	0	0
Indirect charges at 46 per cent. as before	0	18	6
Machine time, 6 hours at, say, 2*s.* 1*d.* per hour	0	12	6
Metal as before, at 10*s.* per cwt....	5	0	0
Total	8	11	0

Or 17*l.* 2*s.* per ton.

In addition to the advantage of increasing the output at reduced cost the castings from moulding machines are better finished, and more true to pattern. With well-designed machines and proper patterns, it is not necessary for the operators to make any skilled use of moulders' tools, and in fact it is found more economical to knock out a damaged mould and try again, than to attempt to repair it. At the same time less dressing, or fettling, is required and the cost of the machining is reduced, because less allowance is required on the pattern, and the castings are more easily "jigged" for machining. All these remarks show the necessity of a carefully kept costing system so that the advantages of improved methods may be quickly and accurately estimated.

In conclusion, he hoped he had fulfilled the conditions laid down in the circular issued by the council when asking for subjects to be suggested for topical discussion "which, briefly introduced, have often given rise to instructive discussions." He looks upon the introduction of a topical discussion as the antithesis of a formal paper, in that the author of a formal paper is expected to defend the same against all comers, whereas a topical discussion passes the responsibility for the arguments on to the audience, and all the first speaker is expected to do is to state his question in an intelligible manner, leaving the rest of the proceedings to the members present.

Acknowledgment should be made to several friends who have kindly supplied information, namely, Messrs. Ashwell and Nesbit, Limited, Leicester, and Messrs. Rose, Downs and Thompson, Limited, Hull, for detailed information as to their systems of foundy costing; Messrs. the Horsehay Company, Limited, Shropshire; Messrs. Buckley and Taylor, Limited, Oldham; Messrs. The Mirrlees Watson Company, Limited, Glasgow; Messrs. Reavell and Co., Limited, Ipswich; Messrs. Ruston and Hornsby, Limited, Grantham; Messrs. R. Williamson and Son, Workington, and particularly to Messrs. Pollock and Macnab (Subsidiary), Limited, Bredbury, and Messrs. Hans Renold, Limited, Didsbury, for the samples of job tickets and fiscal period cards respectively circulated to the meeting.

DISCUSSION.

Mr. Stubbs, who was in the chair, opened the discussion by mentioning that iron founding seemed to be looked upon now from a very different standpoint than that adopted previously, which was all to the good.

Mr. Butterworth had found it an advantage to estimate costs by two alternative methods, and to use one method to check the other. Establishment charges should be allocated to each department as melting, moulding, fettling, and then each moiety distributed over the work done by the particular department. He mentioned that while it used to be the general practice to clear the moulding shop floor by unskilled labour, so that the skilled moulders had a clear start each morning, this practice had fallen into neglect during the later period of the war owing to labour conditions and the greater relative advance in cost of unskilled labour as compared with skilled labour.

Mr. W. H. Cook said money could be made even yet in a foundry by proper methods, and asked what was the advantage of trying to divide up costs in such great detail for a jobbing foundry. He considered it impossible to divide establishment charges properly amongst the various castings produced. He did not agree that it had only recently become general to book moulders' time direct to the job. Owing to present market conditions he was now using 75 per cent. scrap and 25 per cent. pig-iron. He did not attempt to separate cost of melting from the labour costs, although he kept careful record of the amount of fuel, &c., consumed. He also recorded the weights of "gits," bad castings, &c., and found the loss due to melting to be about 4 per cent. He said card systems were good up to a point, but must not be carried too far. Finally he handed in a sample monthly cost sheet that he had used in his own foundry for many years.

Mr. George Kay said that after forty years' experience of weighing every pound of iron charged to cupola, he had found the loss in melting to be 15 per cent.

Mr. Harper said he endeavoured to arrive at the cost of the molten metal, including everything in this item that could possibly be charged. His experience was with light and medium castings, "cored" and plain, and he found a difference in cost between them of 10*s.* per hundredweight. As his dressing or fettling was done piecework he was able to treat this item on a straight tonnage basis. He found it sufficiently accurate to base his establishment charges on wages only, and this method simplified estimating which, after all, was the main object to be kept in view.

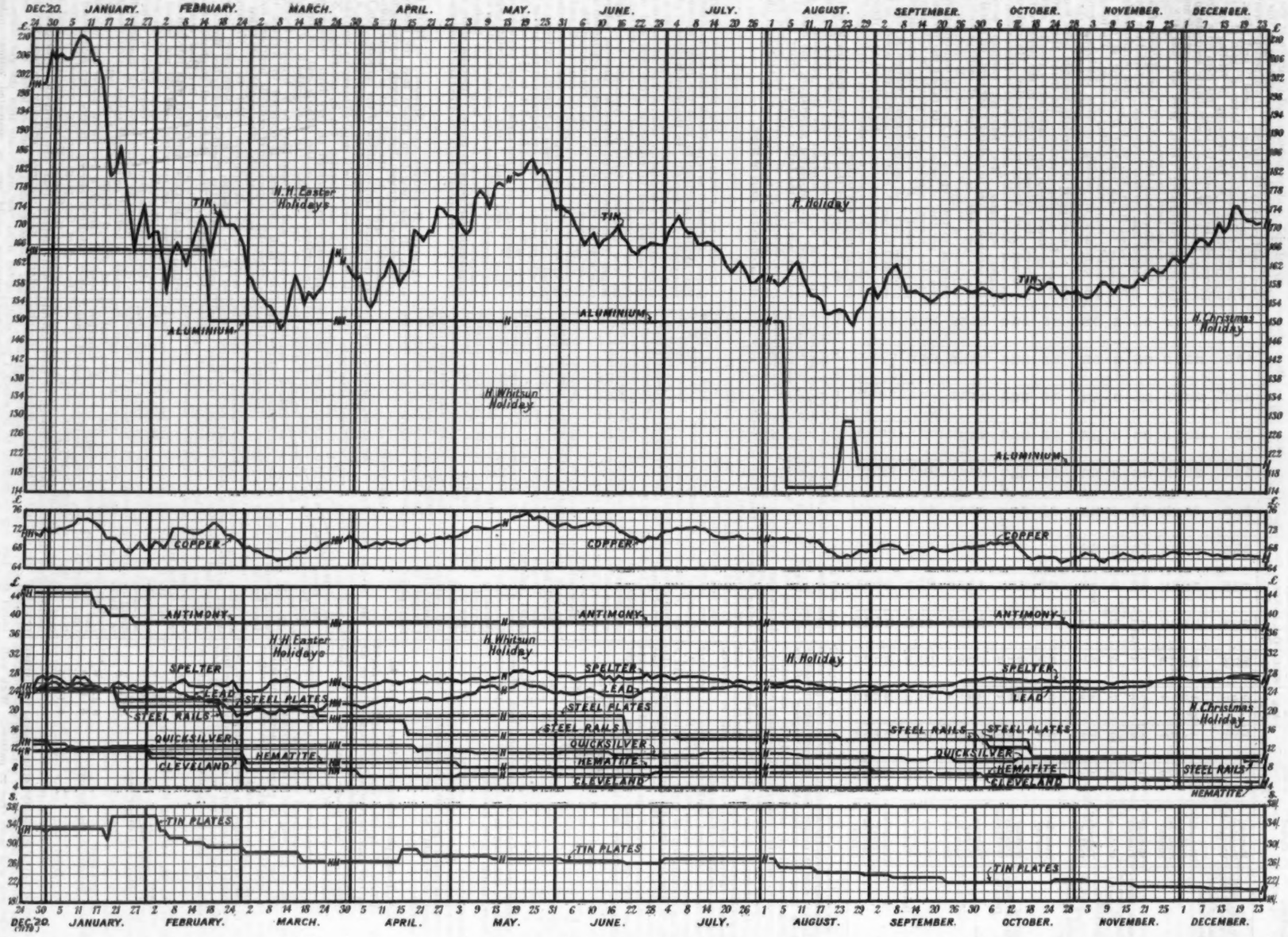
Mr. Bentham said that while his average cost of casting was about 55*s.* per hundredweight, he found the detailed costs varied from 35*s.* to 125*s.*, thus emphasising the necessity for some method of arriving at costs more accurately than merely taking averages. He instanced the difficulty of getting intricate castings through a foundry, when plain ones were going through at the same time, as showing that a straight tonnage basis was not reliable for costing purposes. He found that 100 per cent. on direct labour gave satisfactory results, and had compared the method illustrated in the paper with his own and found the results very similar. He made up his own cost sheets weekly and thus kept in closer touch when making estimates. His defective castings averaged 4·6 per cent.; loss in melting 6 per cent. on metal cast, but 10 per cent. on the weight of castings only, *i.e.*, exclusive of "gits," runners, &c., 25 per cent. was returned to the cupola and his coke consumption was 300 lb. per ton of metal. He raised the question of whether current market prices should be taken for the pig-iron used. He said that having ascertained the probable ratio of establishment charges it was more essential to watch costs of material and labour, as being the more important items. He believed that these discussions would improve conditions in foundries to everyone's ultimate advantage.

Mr. Fielden said that while foundries would certainly vary in details, yet the paper dealt with the various questions in the abstract for the guidance of those interested. He suggested ascertaining the cost of the molten metal in the ladle including labour up to that point, then the cost of moulders' time booked directly to the job should be taken, and establishment charges allocated on the total of these.

GYPSUM IN AUSTRALIA.—The preparation of gypsum is now established as a profitable industry in Australia. But further enterprise to meet the large demand for this product is wanted. In the manufacture of plaster and cement, artificial alabaster and paints, as a flux in metallurgy, a fertiliser of soils, and as a filling for paper and textiles, and in numerous other arts and crafts, supplies of gypsum are required. Its use by the builder is on the increase. Hitherto Australia has imported largely from the United States of America, where the consumption of gypsum per head of population is six times greater than in the Commonwealth. But Australia is fully able to supply its own needs, and even to export. Extensive deposits at Lake Macdonnell, in South Australia, and Tresco in Victoria, are being worked at a high profit. There are deposits at the former place covering 30 sq. miles, and from 3 ft. to 1½ ft. in thickness. The mineral occurs on the surface in the forms known as "flour," "seed" and "rock," or granular gypsum; and below it lies sufficient magnesium-chloride to supply Australia and provide for a large export business in magnesium for years to come. Australia offers a fine field for future operations in the directions thus indicated.

CATHODIC HYDROGEN AND NITROGEN AT HIGH PRESSURES.—It has long been known that the electrolytic generation of hydrogen does not merely depend upon the potential applied to the cell, but is largely influenced by the nature and condition of the cathode. On bright platinum (as distinct from spongy platinum) a considerable supertension is required to evolve the hydrogen; the gas is not liberated, but is, according to Nernst, apparently accumulated at very high pressure within the surface layers of the cathode and not only as a film on the cathode. In the synthesis of ammonia, hydrogen and nitrogen have to be brought together at very high pressures. It occurred to Nithack to try whether this compression of cathodic hydrogen could be utilised in the synthesis. The experiments failed. The results of the experiments which Dr. J. N. Pring and Mr. E. O. Ransome, B.Sc., of Manchester University, described before the Faraday Society last Monday, were also negative. They electrolysed sulphuric acid by currents of 40 volts and 2 amperes in a glass vessel placed within a Mahler-Cook bomb, fed with nitrogen at 125 atmospheres; the ammonia yield did not exceed 0·04 per cent. They then went up to 490 atmospheres in a steel bomb designed by Sir Joseph Petavel. The bomb is closed above by a steel piece with machined flange, which is bedded on a copper spigot in a circular groove and pressed down by a bolt. The nitrogen was admitted through a gun-metal nozzle and this flanged piece. Multiple electric circuits were established with the aid of five plugs radially screwed into the lower portion of the bomb. No ammonia was formed, and it would appear that the cathodic hydrogen cannot interact with nitrogen, probably because the hydrogen passes within the surface layers of the cathode metal from the ionic state into the gas state. The nitrogen would not be activated either under the experimental conditions.

DIAGRAMS SHOWING FLUCTUATIONS IN THE PRICES OF METALS FROM CHRISTMAS, 1920, TO CHRISTMAS, 1921.



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given in the case of steel plates are for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for the East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of tin-plates is per box of I.C. cokes f.o.b. at Welsh ports, but in all other cases the prices are per ton. Each vertical line in the diagram represents a date, and the horizontal lines represent £1 each, except in the case of the diagram relating to tin-plates, where they represent 1s. each.

NOTES ON MOTOR CAR GEAR-BOXES.*

By H. F. L. ORCUTT.

(*Concluded from page* 872.)

COSTS OF PRODUCTION.

In no way are the anomalies and weaknesses of the gear-box so clearly revealed as through an investigation of costs of production. Such an investigation is specially recommended as a stimulus to reform in design and in methods of production. It will reveal that when the best running qualities are desired in proportion to its size, number of parts, and machine operations, the gear-box is a costly unit. It will reveal that a box with almost any elaboration of design necessary to secure good running qualities will be cheaper to produce than the conventional type with all its uncertainties of costs, both direct and indirect. With some makers gear-box troubles are accepted with a hopeless fatality that has pretty nearly killed interest in its improvement. The gear-box "tinker" is looked upon as a necessary member of the staff—he is too often the "key "to the output Even if some repetitions must be indulged in, it will be well to consider the gear-box especially from the standpoint of costs.

With regard to costs, motor car boxes may be broadly divided into two classes : Those in which the costs are known, and those in which they are unknown. The "known" class includes those boxes which are produced under well-organised conditions, where labour-saving machines are properly equipped with up-to-date tools. Wide clearances are allowed, limits are not very fine. no fitting is called for ; costs of assembling are low and it is done by unskilled labour. The teeth of gears are cut with plenty of backlash, with no stoning, or "running in," and no scrap. Noisy running is tolerated, boxes are never pulled down after road tests. The costs of these boxes are low, and in many cases they give good service, but are nearly all very noisy. There is nothing in the problem of production of this class of box that is not well within the capacity of most makers of components. All the machine operations are of the ordinary class, the costs of which are common knowledge. The foregoing applies principally to the so-called three-speed box. As long as the public is satisfied with their running qualities, so long will the maker continue to supply this class of work.

The "unknown" class of gear-box might well be called the "unlimited" class as far as costs are concerned, for many makers never stop work on them until they run to the satisfaction of their road testers. They may pull them down once or a dozen times ; work is put into them regardless of expense and time—the whole output of cars is often held up through faulty gear-boxes. A forecast of their cost is impossible, and an estimate of what they really do cost is so involved and mixed with other costs that no exact figure can be given. Hundreds of pairs of gears have been seen in more than one motor car works which are thrown aside as scrap. In many works all costs on gear-boxes after the first machining and bench work are charged either to erecting and testing, or considered a part of "on-cost." Much depends on the degree of silence that is expected. Some well-known makers are content with silent running for the constant-mesh gears only, others add the third speed. Quiet running on second and first speeds is given up altogether, and reverse gears are rarely bothered with, no matter how badly they may run. Very few indeed make any attempt to secure equally quiet running on all speeds. In those boxes where the best running qualities are desired, costs are usually enhanced by inaccurate machine work. It should not be forgotten that the central idea should be so to design and make the gear-box that it will support accurate tooth contact. Limits of workmanship have been given without which the best results will not be secured in any design. These limits are adhered to by but very few makers of either good, bad or indifferent boxes. Inaccurately-seated ball bearings are a fruitful source of unnecessary costs. They have a narrow face compared with the diameter. For this reason they can be easily tilted in the casing. The outer ring should fit in the housing to a nicety which closely approaches gauge work. They can be easily pushed home in such a manner as to permanently upset the soft metal casing, resulting in more noise perhaps from bearings than from the gear teeth. Dismantling and re-assembling gear-boxes alone often cures this defective alignment, certain noises disappear but costs are increased. Hole-grinding in gears is not always kept within the limits necessary for good mounting. Bad broaching is common, and combined with inaccurate shaft work runs up fitting costs and often neutralises good work on gear teeth. An examination of a large number of splined shafts reveals the fact that in many the finish-ground cylindrical surfaces are not concentric. This is largely due to bad centreing. Results—bearings do not line with each other and gears run out. Bad workmanship in splined shafts and gear teeth is the rule, not the exception. The limits which should be observed on these details have been given above. The added costs due to the defects mentioned are naturally uncertain, irregular and difficult to assess. They include "running in" and hand-stoning gear teeth, fitting which is wholly unnecessary, dismantling and re-assembling, and road testing wholly for gear-box rectification. With many makers road testing for gear-box troubles alone is a formidable item of costs which is wholly chargeable to gear-box production. These costs include wear of tyres, petrol, testers' time and general mileage costs, all not infrequently repeated a number of times. Scrap parts are often a large item in costs, and are wholly unnecessary.

* Paper read before the Institution of Automobile Engineers, December 15, 1921.

Regardless of design, the best running results can only be expected where correct and uniform workmanship is the rule. With correct workmanship, gear-box assembling should be an unskilled operation, even when the best results are expected. There should be no fitting work whatever. Gears need no stoning or "running in," boxes should not be dismantled and re-assembled, special road tests should not be required. Scrap is unnecessary. The designer should be the first to insist on good workmanship, for without it he cannot trace inherent defects, nor try out improvements with any certainty. The engine designer would never have made the progress which he has if he had not been backed by the superior workmanship which is commonly found in the motor car engine. Very few makers would consider for a moment assembling an engine with its principal components made with the indifferent workmanship we usually find in the gear-box. It is doubtful if there is any other working surface in the motor car except the gear tooth which is hardened after it is carefully machined. As with the engine or the axle, the cheapest box is the one which is accurately machined, that is, if the best results are desired. The difference between the costs of irregular and regular machine operations is small, inspection costs may be slightly increased ; assembling and fitting costs are the lowest when good machine work can be relied upon.

As to costs of scrap on gears when they are finish-ground, many records show that 1 per cent. is ample allowance. The same figure can be taken for splined shafts when they are correctly machined.

The greatest interest naturally centres on the cost of gear-teeth finishing, as this is the most costly of any machine operation in the gear-box. The producer has the choice of various methods. There is not much difference in the costs of ordinary gear-cutting when the best machines are employed in either the generating, hobbing, or plain milling processes. Good, bad and indifferent qualities of work are produced by all methods, much depending on experience and on the methods and supervision employed.

When results are desired which call for gear-tooth treatment after hardening, there is a choice of three methods :—

1. "Running in" and stoning.
2. Finishing with a cutter.
3. Grinding with the abrasive wheel.

Grinding with the abrasive wheel gives a quality of tooth form that cannot be produced by any other method ; this quality includes theoretical accuracy as well as uniformity, and when the highest quality is required it is the cheapest. When design is suited to production and quantities are possible, gear-tooth grinding adds little, if any, to the cost of the gear-box. Quality for quality, it is the cheapest method that can be employed when total costs are considered. Stoning and "running in" are makeshift processes, irregular in cost and quality. Finishing with a cutter after heat-treatment gives better results than hand-finishing. The greatest additional cost is in maintenance of cutters, which wear rapidly. Strict supervision is necessary to maintain uniformity—only certain grades of hardness can be tolerated. Accuracy of tooth form necessary to very quiet running is impossible.

As a means of reducing costs and assisting to regular output, accurate machining of the splined shaft is second in importance to gear-tooth finishing. There are three forms of shafts for driving gears : the square shaft, the cylindrical shaft, with an inserted key, and the so-called splined shaft. The splined shaft is used in two ways, with the gears mounted on the tops of the keys, and with gears mounted on surfaces between the keys. There is only one method of driving which is recommended as possessing the combined virtues of high quality and low costs. This is found in the splined shaft on which gears are mounted on the circular surfaces between the keys. Mounting gears on the tops of splines or on a square shaft may be considered as a practically impossible method of securing uniform results and one which is consequently costly. The difficulty in both cases is in finishing the inner surfaces of the gear which take the bearing on the shaft. When these surfaces are hardened, costly hand work is necessary to finish them to anything approaching a degree of accuracy. When the gears are mounted on the circular surfaces of the shafts which is between the keys, the hole in the gear can be cheaply ground within fine limits. The splined shaft can also be ground so accurate that no fitting between the two parts is called for, and the gear will run so truly that with good teeth the best possible running qualities are secured. If a box so finished is noisy in running, better workmanship will not cure the evil—design must be studied until inherent defects are corrected and costs due to these defects are eliminated.

There is one peculiar feature of gear-box costs which is worth special examination, and which is not a regular item of production expenses. It is caused by gear-box troubles which are experienced by many makers. These troubles follow intervals of steady output with those who turn out cars of good quality with fairly quiet running gears. Suddenly car after car is turned down by the road inspector and the whole output is held up by gear-box defects. It is a costly business. It is so sudden and disastrous that it might well be termed an epidemic. Investigation often reveals the origin in defective gears, defective in the teeth or mounting. It has been stated that the allowable variation from accuracy in gear teeth is smaller than is usual in the finest grinding work if the best results are desired. The facilities and the experience for keeping gear work within these fine limits exist in but very few workshops. Often large quantities of gears are hardened and completely finished with inaccuracies that can only be detected by a running test. These errors are large enough to cause bad running, but are so small and of such a nature that they are not to be found by ordinary methods of gear inspection. They may be due to the displacement of tooth-form caused by wear in tooth-cutting machines, or in wrongly-shaped or wrongly-set cutters, or an alteration in the heat-treatment. It is usually a costly business to face a trouble of this nature. Gears which are hardened after they are finished and are found to be faulty are not easily recovered. Sometimes the teeth can be ground to correct form so that they run well even with a backlash of 0·025 in. or 0·030 in. If this operation will not save them, they must be added to the scrap heap or badly-running boxes must be accepted. If detailed work on gear-box parts is carried out as suggested, spasmodic troubles of the nature described should not occur. Exact costs of gear-boxes in which the best running qualities are expected should be capable of being forecasted just as well as in those boxes in which noise is considered of no importance. To avoid unnecessary costs care should always be taken to make certain of the origin of the gear-box troubles. Many times it has nothing to do with the box itself ; it sometimes can be traced to defective work in the engine, in couplings or in shafts. When corrections in these parts are made noises in the gear-box disappear.

It may be disappointing that more definite figures as to gear-box costs are not given. They are so difficult to ascertain that exact records are not often kept. As before stated, costs of the original mechanical operations on parts are common knowledge and do not vary to any extent. One thing is certain, the gear-box is more directly responsible for hold-up in output than any other part of the car. This is very costly, and through improved design and workmanship should be eliminated. When it is, exact estimates of costs can be made and relied on. Accurate workmanship is recommended as the indispensable precedent to alteration in design. A complete return of costs should be an indication as to whether the best methods of production are employed or not. Startling revelations await more than one manager who may insist on having a complete return of costs of car production for which the gear-box is directly responsible.

Without doubt, some of the gear-box eccentricities which add to the cost of production are due to heat generated by oil-churning. Thin aluminium casings are easily distorted by heat. Otherwise, the conditions of service which the gear-box has to fulfil are purely mechanical. It should have features of design and specifications of workmanship so that costs could be exactly calculated. Mechanical and assembling operations, clearances, limits, inspections and tests, should be planned as they are for thousands of other mechanisms. In so far as all these details are not definitely dealt with in the course of production, costs will be uncertain. It will, perhaps, be well to repeat the most common workshop irregularities which add to costs :—

Ball bearings badly mounted in casings.

Spigot ball bearings badly mounted in the constant mesh position.

Inaccurate workmanship on splined shafts.

Gears badly mounted, especially when the gears seat on the tops of keys or on square shafts.

Holes in gears ground with too much clearance and too wide limits.

Holes too roughly finished.

Irregular-shaped gear teeth.

Added to these details is the common lack of correct specifications, of clearances and limits, of good methods of inspection. As to design, costs are increased by corrections which must be made in boxes easily deflected by internal strains and chassis distortions, and by badly-designed details. Costs of this nature can only be reduced by the designer himself. There is another detail of design which is often the source of trouble and expense. In both lay shaft and main shaft in many boxes it is possible to look up the ball bearings so that they are subjected to permanent end strains. It should not be forgotten that in good ball bearings the clearances are only a few ten-thousandths of an inch, and consequently they can be easily unduly strained. If they are so mounted that they must take a load or resist a strain which they are not made to carry, they will give trouble which is costly to locate and to correct. Correcting the errors of workmanship above mentioned and insisting on an inspection by which limits are kept to specification should do more than reduce costs of production. Running qualities would be much improved in all boxes, and a definite line would be drawn between troubles due to workmanship and those to design. These troubles are so often intermingled that they cannot be clearly observed and correct remedies cannot be applied.

When costs of assembling and erecting are low, it may be assumed that fundamentals of design and methods of production are not bad. Some examples of assembling costs will be given for a few boxes, in all of which the quality of workmanship is the best and the running qualities are satisfactory, although the design is more or less conventional.

Example 1.—A 6-ton lorry gear-box with four speeds and reverse. Time of assembling, 6 hours. Time includes all labour for fitting work and assembling of all parts, bearings, shafts, gears, selector and brake parts. This box is never dismantled, but is put into the chassis and never removed. No parts are scrapped. There is no "running in," nor gear-teeth stoning. The running qualities are the best.

Example 2.—A three-speed and reverse gear-box for 15-h.p. car. Time of assembling complete, 5 hours. The time includes all labour for assembling and fitting shafts, bearings, gears, change-speed levers, all brake parts, speedometer-drive, cover and housing for universal joint. The box has the best of workmanship throughout and the best running qualities.

Example 3.—A 3-ton lorry gear-box with four speeds

and reverse. Time of assembling complete, 4 hours. Labour includes assembling all parts of the box except the brake. These boxes were the subject of special inspection for quiet running. In several thousand boxes there was practically no scrap.

The above times given for assembling include the complete cost of the gear-box from the time the machined parts are received from the stores until the car is ready to deliver to the customer. They are representative of what should be accomplished on any car of the best quality.

There are records of numbers of cases where changes in limits and new specifications of accuracy were adopted, with the result that dismantling, scrapping and repeated road tests were reduced from a large percentage to practically nothing. Better running qualities were secured and costs reduced.

Suggestions on Design.

In Figs. 5 and 6 are shown different designs of gear-boxes, Fig. 5 illustrating the weaknesses of a common design of box, Fig. 6 suggesting lines on which an improved box may be evolved.

The power transmitted in both boxes is 35 b.h.p. at 1,500 r.p.m. The gear ratios are nearly the same, and the gears selected are 6 D.P., 20 deg. angle of pressure.

The contrasting features of design are principally in the method of mounting, the shape and material of the casing, the centre distances between the shafts, and the distance between the bearings. A special feature of Fig. 6 is the central bearing. It is believed that the circular form of the casing in Fig. 6 will resist stresses better than the box form as in Fig. 5. Two methods of mounting the improved design are shown, the object in both cases being to avoid transmitting chassis distortion to the box itself. In Fig. 6 the ball end to the casing could be set in a socket secured to a cross-member of the frame, the rear end of the casing being secured to the torque tube. The front and rear ends would be malleable castings, and the central portion would be of aluminium. With this construction the casing would be well reinforced and further strengthened by a vertical wall in which the central bearings would be housed. In Fig. 6a the box is bolted directly to the engine casing, a practice which is to be noticed in many new designs. It seems to predominate in the American and French cars. A few models are now made with the ball joint and torque tube mounting.

The outside dimensions of Fig. 6 are greater than those of Fig. 5. The distances from bearing to bearing in Fig. 6 are 6½ in. and 6½ in. as compared with 10½ in. in Fig. 5. The centre distances compared are, 4·666 in. in Fig. 6, and 3·9166 in. in Fig. 5, a difference of ¾ in. This increase in centre-distance is fully as important as the decrease in the lengths of the shafts between the bearings. Larger gears can be used, and there is ample space for housing ball bearings which are well above their load. Contrasting velocities, loads and stresses are shown in Table I. The velocities of the gears in Fig. 6 are very little higher than in Fig. 5; the loads and stresses are very much less. Good construction is difficult when the centre-distance between the shafts is small. Sometimes it is so restricted that ball bearings cannot be used with a proper load-capacity, as indicated in Table II. In this table the maximum bearing loads, the revolutions per minute, and the bearings with safe loads as given by the makers, are shown. In the design shown in Fig. 6, it is possible to use ball bearings with safe loads in all cases. In the design in Fig. 5, on account of the close centre-distance, it is impossible to use the makers' "safe-load" ball bearings in bearings 2, 4 and 6. Roller bearings with "safe" loads could be used in 2, 4 and 6. In this case, however, an end thrust bearing should be added in bearing 4. Table III has been compiled to show the maximum and safe loads on bearings which are directly comparable in Figs. 6 and 5. The spigot bearing in Fig. 5 design is shown with rollers. It is often a ball bearing too small to carry the load. Results which are of especial interest seem to be brought about by the introduction of a central bearing as in Fig. 6. Table IV has been compiled to show the effect of this bearing in the distribution and minimising of

Fig. 5. ORDINARY DESIGN OF GEAR-BOX.

POWER TRANSMITTED 35 B.H.P. AT 1500 R.P.M. GEARS, 6 D.P. 20 DEGREES A.O.P.
RATIOS. Top 1:1 3rd 1·55:1 2nd 2·38:1 1st 3·76:1 R 3·10:1

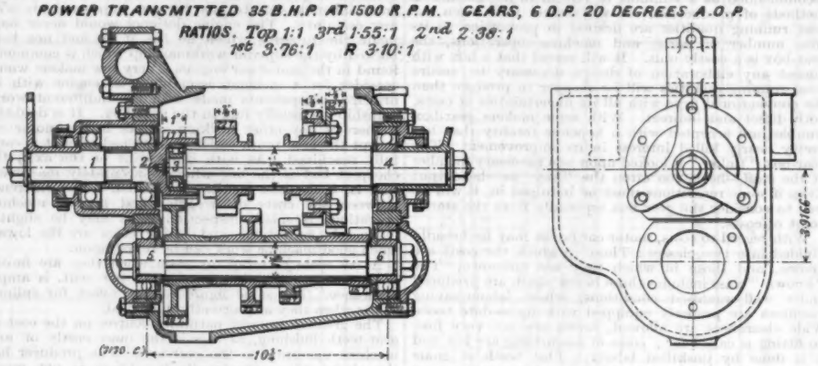


Fig. 6. SUGGESTED DESIGN OF GEAR-BOX.

POWER TRANSMITTED 35 B.H.P. AT 1500 R.P.M. GEARS, 6 D.P. 20 DEGREES A.O.P.
RATIOS. Top 1:1 3rd 1·57:1 2nd 2·42:1 1st 3·79:1 R 3·56:1

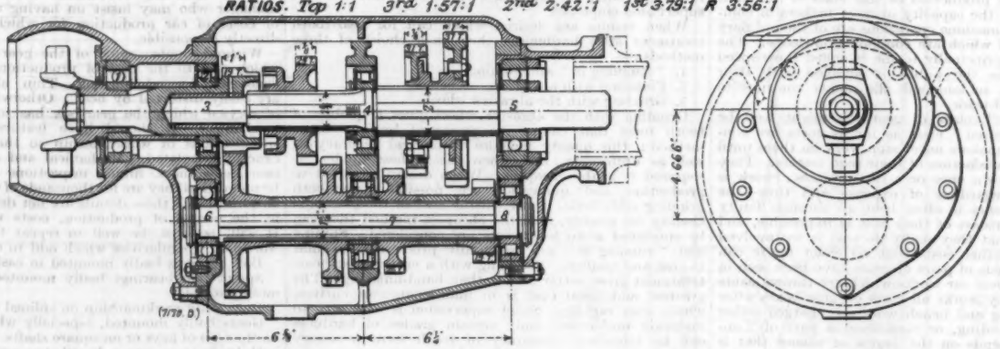


Fig. 6a. SUGGESTED DESIGN OF GEAR BOX ARRANGED FOR UNIT CONSTRUCTION.

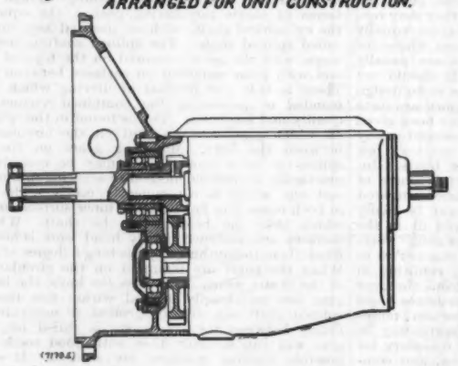


Fig. 7. SHOWING HOW MAXIMUM TOOTH-CONTACT IS OBTAINED WITH PROFILED GEARS.

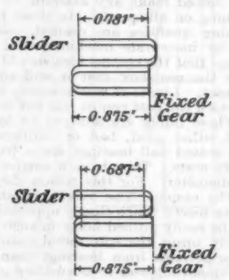


Table I.

Gear.	Gear Velocity, Load and Stress.					
	Pitch Line Velocity.		Tangential Load.		Stress, Lb. per Sq. In.	
	Fig. 6.	Fig. 5.	Fig. 6.	Fig. 5.	Fig. 6.	Fig. 5.
C.M. pinion	1,244	1,114	928	1,038	17,750	20,600
3rd slider ..	1,040	928	1,105	1,240	22,400	25,800
2nd driver ..	840	742	1,370	1,555	27,750	33,300
1st driver ..	638	556	1,805	2,070	34,500	49,250

Table II.

Bearing Number.	Maximum Actual Loads and Safe Loads.					
	Fig. 6.			Fig. 5.		
	Max. Load.	R.P.M. of Bearing.	Safe Load.	Max. Load.	R.P.M. of Bearing.	Safe Load.
	lb.		lb.	lb.		lb.
1	297	1,500	1,540	420	1,500	1,180
2	1,287	1,500	1,500	1,327	1,500	1,180
Spigot 3	262	—	—	862	532	1,220*
4	1,302	620	1,880	1,925	400	1,870
5	1,505	396	2,500	810	850	1,320
6	803	770	1,490	1,870	850	1,320
7	1,030	770	1,890			
8	1,575	770	2,930			

* If a ball bearing is fitted here, as is often the case, it would have a safe load of only 620 lb.

Table III.

Maximum Actual and Safe Loads on Like Bearings in Lb.

Bearing Number.	Fig. 6.		Bearing Number.	Fig. 5.	
	Max. Load.	Safe Load.		Max. Load.	Safe Load.
1	297	1,540	1	420	1,180
2	1,287	1,500	2	1,327	1,180
3	262	—	3	862	1,220
5	1,505	2,500	4	1,925	1,870
6	803	1,490	5	810	1,320
8	1,575	2,930	6	1,870	1,320

loads. The maximum bearing load in Fig. 6 is 1,575 lb.; in Fig. 5, 1,925 lb. The minimum load in Fig. 6 is 0; in Fig. 5, 275 lb. It is instructive to contrast the loads on individual bearings. The spigot-bearing is an inherent

weakness of the standard gear-box. With the central bearing this weakness is partly neutralised. The overhung ball race in Fig. 5 supporting the spigot end of the main shaft should be contrasted with the plain spigot bearing in Fig. 6 which is seated well inside the constant-mesh pinion. In Fig. 6 this bearing on the first speed and second speed takes no load; in the third speed it takes 262 lb. contrasted with first, second and third speeds in Fig. 5 of 275 lb., 758 lb. and 862 lb. respectively. Bearing No. 6, in Fig. 5, is a bearing which in nearly all four-speed boxes takes the heaviest load when the first-speed gears are engaged. In the box of one well-known car two ball bearings are used in this position. The contrast is, in Fig. 6 (bearing 8), 1,575 lb., in Fig. 5

TABLE IV.

Bearing No.	Loads in Lb.					
	1st Speed.		2nd Speed.		3rd Speed.	
	Fig. 6.	Fig. 5.	Fig. 6.	Fig. 5.	Fig. 6.	Fig. 5.
1	297	420	297	335	297	340
2	1,287	1,327	1,287	1,045	1,100	1,045
Spigot						
3	0	275	0	758	262	862
4	415	1,925	1,202	897	918	458
5	1,505	810	258	635	0	630
6	803	1,870	803	900	650	480
7	230		1,030		820	
8	1,575		292		0	

TABLE V.

Gear.	Tooth Pressure per Inch. Contract.					
	Total Face, In.		Actual Contact, In.		Lb. per In. of Contact.	
	Fig. 6.	Fig. 5.	Fig. 6.	Fig. 5.	Fig. 6.	Fig. 5.
	in.	in.	in.	in.		
C. Mesh. 3rd Speed	1·0	1·0	1·0	1·0	990	1,100
2nd Speed	0·875	0·875	0·781	0·687	1,510	1,920
1st Speed	0·875	0·875	0·781	0·687	1,870	2,410
	1·0	0·875	0·8125	0·687	2,360	3,200

(bearing 6), 1,870 lb.in.; Fig. 5 (bearing 4), on first speed the load is 1,925 lb., compared with Fig. 6 (bearing 5) on first-speed, 1,505 lb. There are several instances where the loads on bearings in Fig. 6 are heavier than on the same bearing in Fig. 5. As pointed out, the increased centre-distance in Fig. 6 allows the use of bearings with plenty of surplus capacity. In Table V tooth pressures are contrasted. The difference in favour of gears in Fig. 6 is due to the widths of the gears and to sliding the gears so that the full possible working tooth contact is made use of. This is often overlooked in the standard type of gear-box. Fig. 7 shows the method of overlapping suggested, which increases the length of the box by ½ in.

The gears in Fig. 6 are reduced in variety as far as possible. The gear teeth numbers are duplicated; there are two 19-teeth, two 25-teeth, two 31-teeth, and two 37-teeth gears. The variety of teeth in the gears in Fig. 5 is quite common, and is an unnecessary addition to costs and trouble in gear-tooth finishing. The gears in Fig. 6 are in all cases designed to facilitate the cheapest production on the most costly operation, that is, tooth-finishing. Some of the gear teeth can be finish-ground, four at one setting. The sliding gears in Fig. 6 have a much better seating on the main shaft than the sliding gears in Fig. 5; the space between the fixed gears is, however, greater in Fig. 6 than in Fig. 5, but shaft deflection is prevented by the central bearing. That portion of the main shaft on which the second and first-speed gears slide, is made larger in Fig. 6, principally to facilitate assembling. The particular design of the first, second and third-speed sliders is suggested in Fig. 6, so that these gears, when under load, will be close to the supporting bearings. As the gears taking the heaviest loads, the first speeds in Fig. 6 are made with a wider face than the third and second-speed gears.

Recommended methods of locking up bearings are shown in Fig. 6. They are so locked that the end thrusts are taken on the ball bearings Nos. 1, 5 and 6. The other bearings are rollers and have a free end movement. With this construction it is impossible to throw loads on to the ball bearings which they are not made to carry. It hardly needs to be mentioned that with the central bearings all gears are well supported when under load, much better, indeed, than they would be with abnormally large splined shafts with no central bearing. Production costs of a box made on the lines suggested in Fig. 6 should be put little in excess of those of a box as in Fig. 5. The number of parts is increased by two central bearings, and the end pieces to the casing are more expensive. Weight will be somewhat increased, but this is essential to substantial mounting for highly-stressed gearing. For many years the endeavour has been made to get good results from the conventional design—it has failed. The motor car maker must decide whether he will carry on with the old type or not. No box is known in which are embodied all the principles shown in Fig. 6, though each separate detail is to be found in different boxes. To get the best results they should be combined. To do this and not increase weight over that of the usual design is impossible. As previously stated, stability and rigidity must be the guiding principles of gear-box design. These principles cannot be adhered to if flimsy construction is permitted. With correct methods of manufacturing, total costs of production of an improved design need not exceed those now paid when the endeavour is made to supply a good running box of inferior design.

Fig. 6 is intended to illustrate as far as possible the principles which must be followed in gear-box design if quiet running is desired. No claim can be made that a box exactly as shown will be the ideal box. As before stated, such a box cannot be produced without individual experimental and development work. Design will vary, of course, to meet the service called for by the car in which it is mounted.

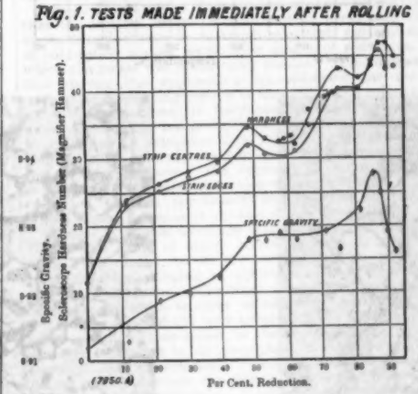
EXPERIMENTS IN THE WORKING AND ANNEALING OF COPPER.

By F. JOHNSON, D.Sc., Member (Birmingham).*

SECTION I.

IN a previous contribution (see ENGINEERING, vol. cix., page 401) the author described a series of experiments on copper which had been cold-rolled in successive passes without annealing. Curves plotted from the test results of the rolled strips indicated that there were several stages (critical ranges of deformation) which appeared to be similar in character to the critical range first discovered by Alkins, in copper which had been cold-drawn. There are, as the author has already pointed out, inherent disadvantages from the experimental point of view in testing rolled strips of varying thickness, chief of which is the differential distribution of stresses and strains, and therefore a variation in physical properties in a given strip. The strips may be too thick or too wide to test without slitting, an operation which can be arranged so as to yield test-pieces from approximately the same position, *e.g.*, down the longitudinal axis of the rolled piece—but which can never, without considerably greater knowledge of the distribution of strains than is at present available, give a series of test-pieces in which there is only one variable factor, viz., percentage reduction of thickness. Even if the limitations of testing machines could be overcome, the testing of complete lengths of strips without cutting would be unsatisfactory because of the unevenness of the edges and the difficulties of accurate gauging.

Fig. 1. TESTS MADE IMMEDIATELY AFTER ROLLING



This paper will not contain any reference to attempts to overcome this particular disadvantage, although possibly the employment of a rolling-mill giving a closed pass would lead to a mitigation of the difficulty.

The employment of strips of such width that the variation in properties over a considerable area down the centre would be negligible, would however, probably provide the best solution of the problem.

In order to ascertain the possible effect of time on the hardness and specific gravity of rolled copper, the author took a piece of the billet used in his earlier experiments and planed it to a thickness of ½ in. The planed strip, 1½ in. wide, was cold-rolled in a small pair of rolls (3 in. diameter) worked by hand. Immediately after rolling, the strip was tested for hardness by the scleroscope, the heat developed by friction being first removed by cooling in water at room temperature. A sample was then sawn from the strip representing its full width, and its specific gravity subsequently determined, adopting all the precautions possible in the determinations. A human hair was used as the suspensory thread, all grease was carefully removed from the specimen, and water which had been allowed to arrive at room temperature was used. The samples weighed 10 grammes to 20 grammes each.

The rolling and hardness tests occupied two days. The specific gravity tests were completed in five days.

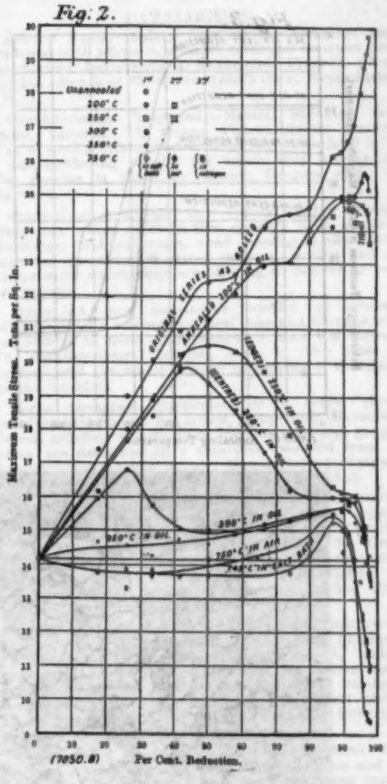
Hardness Determinations.—The hardness determinations down the centre of the strips differ from those taken along the edges, being consistently higher.

It is also of importance to note that the critical ranges of deformation (Fig. 1) show an unmistakable diminution of hardness over the critical range. This was foreshadowed by the author's earlier experiments, and it would now appear that an ageing effect takes place, whereby, after a certain lapse of time, the temporary diminution in hardness caused by cold-rolling disappears.

Whatever the cause of this temporary forced plasticity, these experiments amply confirm the observations of practical tubedrawers and other workers in metal, who have taken advantage of it in their practice to perform alterations of shape, &c., before the ageing effect could take place. The author's results do not, however, reveal temporary plasticity for every pass.

Specific Gravity Determinations.—The results of these are plotted in Fig. 1, and it will be seen that, although not exactly parallel in behaviour to the alterations in hardness, the volume changes which the specific gravity changes denote show a critical range and, what is extremely interesting, show up to a percentage reduction of 85, a diminution of volume rather than an increase, as shown by Alkins for wire-drawn copper. These results are in confirmation of other results obtained by the author and described in his previous paper. It would certainly appear as if the volume changes produced by wire-drawing are of an opposite nature to those produced by cold-rolling. As before mentioned, there is no consistent agreement between the hardness and volume changes.

Fig. 2.



SECTION II.

Annealing of Rolled Strips.—As there was a limited quantity of rolled metal left over from the author's previous investigation, it was thought that a number of complete sets of test specimens could be made up for the purpose of subjecting them to annealing at different temperatures. Unfortunately two difficulties presented themselves, viz.: (*a*) Insufficiency of material from some of the "passes"; (*b*) preparation of specimens of comparable shape and origin. The first difficulty (*a*) could not be avoided, and the best use was made of such material as was available. The second difficulty (*b*) could not be completely met, but care was exercised in slitting, so that each specimen represented the full thickness of the rolled strip wherever possible. The variability introduced by horizontal cutting of the strips is almost negligible. It is, of course, possible that at the critical temperature of recrystallization comparison of test results on horizontally cut strips and those uncut would not be fair. Such release of stresses as cutting entails might, it is thought, have an influence in the direction of altering the recrystallization temperature. Research on this point is desirable.

So far as the origin of the test strips is concerned, the slitting was systematically carried out, each test-piece being lettered, and each series of tests being made on test-pieces originating from similar positions in the rolled strip. This identity of origin must inevitably be approximate, as specimens from the strips representing the earlier passes had of necessity to have a thickness greater than their width, whilst the reverse was true of the specimens taken from strips representing the later passes. The author was materially assisted in the preparation of test specimens by Mr. W. B. Shurrock, to whom his thanks are due. Every endeavour was made to secure uniformity of temperature in the

* Abstract of a paper read at the Birmingham meeting of the Institute of Metals, Wednesday, September 21, 1921.

annealing of each batch of strips, and tests taken at various positions showed no variation greater than 2 deg. or 3 deg. C.

An oil-bath, gas-heated and suitably lagged, was used for the low-temperature annealings, whilst the high-temperature annealings were made in (*a*) a salt bath, (*b*) air, and (*c*) nitrogen.

The results of the tests are plotted in the curves shown in Fig. 2.

The chief points of interest are: (*a*) Unmistakable softening, as indicated by a falling off in tensile strength, occurs in all the strips rolled beyond 40 per cent. reduction after annealing at 200 deg. C. The most severely worked strips show the greatest amount of softening. It is interesting to note that the critical range of deformation at 50 per cent. to 60 per cent. reduction appears to have been eliminated by this low-temperature annealing. It is thought that the steps in the curve, shown at the later stages of reduction, must be due to variable factors (involved in the preparation of the strips, &c.), over that of the unrolled bar. This rapid diminution in tensile strength is so marked in the high-temperature annealings as to indicate a very serious permanent disability in the metal produced by excessive rolling. It was thought that the air-annealed specimens might have been susceptible to "burning" and that intercrystalline oxidation at the surface of the thin strips was sufficient to account for the extraordinary loss of strength, (*a*) by forming an embrittled surface layer, and (*b*) by promoting premature rupture in the testing machine. Two other sets were therefore made, viz.: (1) In a salt bath in a Wild-Barfield electrical resistance furnace, and (2) in an atmosphere of nitrogen.

In case (1) some scaling took place, and the possibility of some action at intercrystalline boundaries cannot be eliminated. In case (2), although the nitrogen used was not absolutely oxygen-free, as was proved by the two outer specimens of the pack scaling slightly, the inner specimens came out perfectly bright and free from oxidation. The furnace used was a vertical wire-wound resistance furnace, water-sealed, and the specimens were allowed to fall into the water at the end of the so numerous as in specimens less severely worked, whilst the outlines of the crystals appear to be somewhat rounded. The other specimens of this series are similar, but if anything rather more finely crystalline.

Fig. 7 represents the surface structure of strip No. 18a (97·8 per cent. reduction) after annealing at 750 deg. C. in air. That superficial intercrystalline oxidation has taken place appears to be highly probable judging by the thickness of the boundaries. When examined at a slightly lower depth, the boundaries were normal (similar to those of Fig. 6). The author has already suggested that the presence of this superficial "burnt" layer would account for the extra diminution of strength of the thin air-annealed strips as compared with those annealed under protection. The tensile strength of the strip represented in Fig. 7 was 9·4 tons per square inch, whilst that of the corresponding strip annealed in nitrogen was 11·0 tons per square inch.

Tests for Hardness.—A very large number of sclero-scope hardness tests was made, and the results are in general agreement with the yield point and maximum stress tests. A selection of results is plotted

Fig. 3.

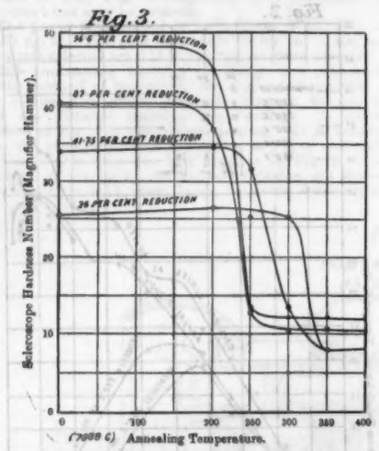


Fig. 4.

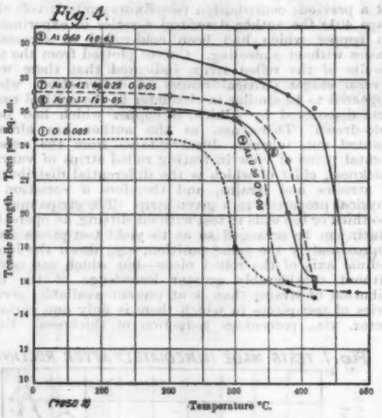
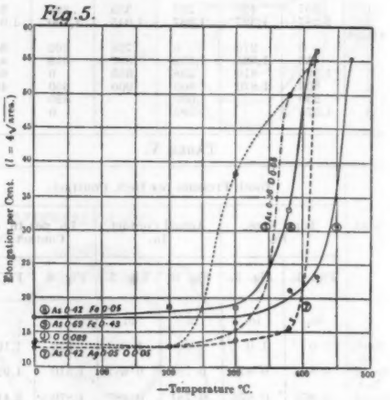


Fig. 5.



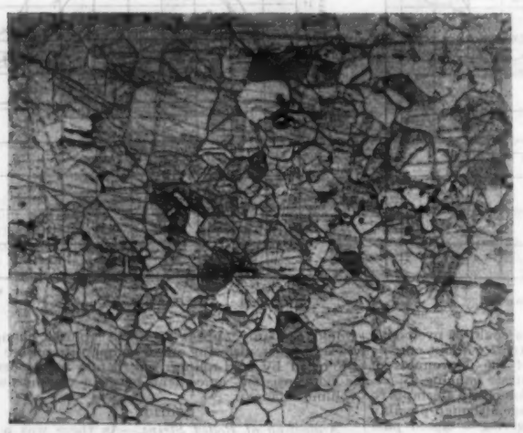


FIG. 6. STRIP NO. 15a (95·75 PER CENT. REDUCTION), ANNEALED AT 750 DEG. CENT. FOR ½ HOUR IN NITROGEN. MAGNIFICATION 100 DIAMETERS. ETCHED IN 10 PER CENT. AMMONIUM PERSULPHATE.

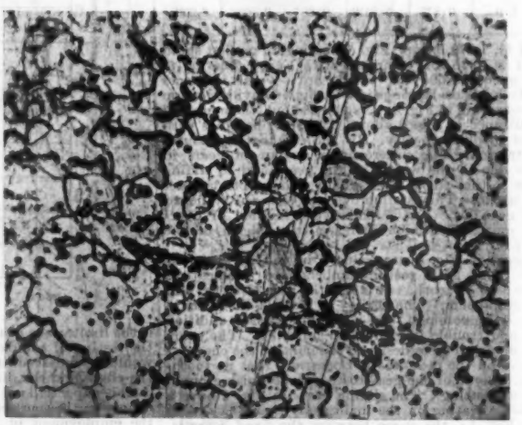


FIG. 7. STRIP NO. 18a (97·8 PER CENT. REDUCTION), ANNEALED AT 750 DEG. CENT. FOR ½ HOUR IN AIR. MAGNIFICATION 100 DIAMETERS. ETCHED IN 10 PER CENT. AMMONIUM PERSULPHATE. SHOWS "BURNT" SURFACE STRUCTURE.

which the author had not full control. Full attention should be given to all preparation details, ageing, influences, &c., in future investigations. The supplementary series of tests at this temperature do not confirm the occurrence of two of the arrests. (*b*) At an annealing temperature of 250 deg. C. there is a remarkable difference in the results of the heavily stressed and lightly stressed specimens. Some of the former are completely annealed, in the sense that the tensile strength has fallen to, or lower than, that of the original unrolled bar. The difference between these results and those of the supplementary series at this temperature is mainly due to the difference of origin of the test-pieces. There is little softening in the test-pieces representing 40 per cent. reduction or under. (*c*) At 300 deg. C. the extra strength conferred by rolling has been nearly removed from practically all the strips, excepting those below 40 per cent. reduction in thickness. (*d*) At 350 deg. C. annealing may be considered to be practically complete for every degree of reduction.

The three series of annealings at 750 deg. C. for 30 minutes show a uniform, if slight, lowering of strength as compared with the 350 deg. C. annealings for 1 hour. It is curious, however, that the tensile strength beyond 70 per cent. reduction rises to a point (85 per cent. reduction) in the neighbourhood of which all the series, with the exception of that at 200 deg. C., show a tendency to fall off rapidly in strength, ultimately to values below annealing period, so as to prevent all possibility of surface oxidation. The thanks of the author are due to Dr. C. M. Walter, engineer to the high-pressure gas department of the City of Birmingham Corporation, for his permission to use this furnace. The yield-point figures have not been plotted for inclusion in the paper, but the curves confirm the features revealed in the tensile strength curves (Fig. 2). In the 300 deg. C. series, only the strips up to 40 per cent. reduction show any of the remanent stiffness conferred by rolling, whilst at 350 deg. C. it has disappeared from all the strips.

Microstructure.—The author made an examination of the annealed strips, but discovered nothing of exceptional interest. The structures were found to be in accord with general principles, the more severely worked strips showing recrystallization at an earlier stage than the lightly worked ones, the grain size of the latter being larger after the completion of recrystallization. The strips annealed at 750 deg. C., showing such a serious falling off in tensile strength, were carefully examined, but so far no explanation can be offered for the deterioration. The deterioration is not due to coarseness of grain, as may be seen from Fig. 6, in which is shown the structure of strip No. 15a (95·75 per cent. reduction) after annealing in nitrogen. The tensile strength of this strip was 12·4 tons per square inch. The grain size is certainly not excessively coarse, nor are there any signs of intercrystalline weakness. Twinned crystals are not in the form of hardness-annealing temperature curves in Fig. 3.

In a paper read by Cæsar and Gerner, the authors claim that their tests show that for copper, "the greater the degree of cold reduction (by rolling) the narrower the temperature zone of rapid softening." Whilst the author's tests do not confirm this conclusion, it is felt that further work is necessary before it can be definitely opposed.

SECTION III.

Influence of Impurities on Effective Annealing Temperature of Cold-Drawn Copper.—In this section are described the results of a few experiments, limited in number by the amount of material available.

The latter was in the form of hot-rolled copper rod which remained in the author's possession after the completion of some earlier experimental work. It appeared to the author that this material having been carefully analysed could be made to serve some useful purpose, and it was therefore decided to subject it to cold-work and examine its behaviour at low-annealing temperatures.

The rod was 0·5 in. diameter as rolled (hot), and the compositions were as given in Table I.

The rolled bars were subjected to the following treatment:—

Annealed at 640 deg. C. for 20 minutes.

Cold-drawn in one draft to 0·478 in. diameter.
Annealed at 640 deg. C. for 30 minutes.
Cold-drawn in four drafts to 0·298 in. diameter.

A preliminary experiment was made on rod No. 2, to see whether any difference of mechanical properties would be observable between the rod as drawn and as turned in the lathe. No appreciable difference existed between the tensile properties of the unturned and turned rods. This is important as, during the course of the investigation, the rods were tested after turning owing to the desire of the author to determine the limits of proportionality. It was found, however, that the rods were not, even after turning, truly straight, having left the drawbench very slightly curved, quite sufficient curvature remaining to render extensometer determinations worthless.

TABLE I.—*Analyses of Rods.*

No.	Copper. per cent.	Oxygen. per cent.	Arsenic. per cent.	Iron. per cent.	Silver. per cent.
1	99·90	0·089	—	—	—
2	99·44	0·026	0·526	—	—
3	99·57	0·052	0·361	—	—
4	99·56	0·060	0·410	—	—
5	99·61	0·056	0·300	—	0·042
6	99·31	0·058	0·453	—	0·175
7	99·26	0·048	0·423	—	0·290
8	99·56	nil	0·370	0·05	nil
9	98·89	nil	0·69	0·43	nil

The results of the mechanical tests on all the experimental rods as drawn are given in Table II :—

TABLE II.—*Tests on Rods as Drawn and Turned.*

No. of Rod.	Description.	Maximum Stress. Tons per Sq. In.	Elongation per Cent. = $4\sqrt{\text{area}}$.
1	Electrolytic "tough pitch" (0·089 per cent. oxygen) ..	24·45	13·5
2	Arsenical (0·026 per cent. oxygen)	26·27	14·5
3	Arsenical "tough pitch" (0·05 per cent. oxygen)	26·3	13·65
4	Arsenical "tough pitch" (0·06 per cent. oxygen)	26·08	11·1
5	Arsenical "tough pitch" (0·04 per cent. silver)	26·3	14·6
6	Arsenical "tough pitch" (0·175 per cent. silver)	26·9	12·9
7	Arsenical "tough pitch" (0·29 per cent. silver)	27·25	13·1
8	Arsenical, deoxidised (0·05 per cent. iron)	26·4	16·9
9	Arsenical, deoxidised (0·43 per cent. iron)	30·03	16·9

The rods were annealed at temperatures of 200 deg., 300 deg., 380 deg., and 470 deg. C. The first temperature was obtained in an oil-bath, the data being as follows. The oil-bath was at a temperature of 205 deg. C. when the rods were introduced. This fell to 192 deg. C., and it took 12 minutes for the temperature to reach 200 deg. C., at which it was maintained for 30 minutes. In the experiments at 300 deg. C. and over, an electrically-heated (platinum wound) tube furnace was used. The furnace temperature was 300 deg. C. when the rods were introduced, which caused the temperature to fall to 220 deg. C. An interval of 20 minutes elapsed before 300 deg. C. was again reached, which temperature was maintained by means of an external adjustable resistance for 30 minutes.

For the other periods of annealing the data were as follows :—

380 deg. C. Period.

Preheating period to 380 deg. C. ... 13 minutes.
Annealing period at 380 deg. C. ... 30 minutes.

420 deg. C. Period.

Preheating period to 420 deg. C. ... 13 minutes.
Annealing period at 420 deg. C. ... 30 minutes.

470 deg. C. Period.

Preheating period to 470 deg. C. ... 13 minutes.
Annealing period at 470 deg. C. ... 30 minutes.

The curves in Figs. 4 and 5 afford interesting confirmation of the results obtained by Cæsar and Gerner, and by Mathewson and Thalheimer, together with indications of additional influences. The results show that the arsenical rods, Nos. 2, 3, and 4, retain their strength practically unimpaired at 300 deg. C., whereas the electrolytic rod, No. 1, has undergone very considerable softening. The arsenic content varies from 0·36 per cent. to 0·52 per cent. and the oxygen content from 0·026 per cent. to 0·06 per cent.; that of the electrolytic specimen (No. 1) being rather higher, viz., 0·089 per cent.

An increase in the oxygen content was shown by Cæsar and Gerner to have little influence on the temperature of recrystallisation, after the first addition of 0·03 per cent. had effected a lowering of that temperature some 25 deg. C. These four rods may therefore be considered to be fairly comparable for determining the extent of the influence of arsenic of the order of 0·5 per cent. upon the recrystallization temperature of copper containing cuprous oxide.

Arsenical rods of similar composition, but with the addition of silver (Nos. 5, 6, and 7), show similar properties to those of the arsenical rods free from silver (2, 3, and 4). The softening of rod No. 7, containing 0·29 per cent. silver, occurs at a slightly higher temperature than the others, the increase in elongation at 380 deg. C. being indeed hardly appreciable, while that of rod No. 5 (0·04 per cent. silver) has risen to its maximum at this temperature. Hence it would appear that a certain minimum proportion of silver must be present in order to effect any raising of the recrystallization temperature of arsenical copper containing cuprous oxide. The Shore hardness-annealing temperature curve of Cæsar and Gerner, for oxygen-free copper containing 0·10 per cent. silver, agrees fairly well with the author's strength-annealing temperature curve for rod No. 7 (0·29 per cent. silver), the softening taking place rather earlier in the former case.

In rod No. 7 there is something by way of a compromise between the cuprous oxide and the metals in solid solution.

Rod No. 8 is an interesting comparison with rod No. 3, the sole difference being the substitution of 0·05 per cent. iron (No. 8) for 0·05 per cent. oxygen (No. 3). Softening commences at practically the same temperature in each, but the softening range of temperature is wider in the case of No. 8. This result is hardly in accordance with what might be expected from a knowledge of the work of the American authors already mentioned. Therein it is shown that cuprous oxide tends to initiate recrystallization earlier rather than to narrow the softening range of temperature. Whilst this is not borne out by the author's results, it must be remembered that arsenic is present in both of the rods under discussion, whereas it was absent from the strips examined by Cæsar and Gerner.

The superior ductility of rod No. 8 (free from oxygen) in the cold-drawn condition is worthy of note.

Perhaps the most interesting results of the whole series are those obtained with rod No. 9 containing high arsenic and high iron content. The improved properties are largely due to the iron content. It will be seen that the strength of this rod, although actually commencing to decrease at 300 deg. C. or even earlier, does not show signs of entering the "region of rapid effects" until a temperature of 420 deg. C. has been reached. At this temperature the rod has lost about 12 per cent. of its strength as drawn, whereas rod No. 8 has lost 38 per cent. The very wide softening range of the iron-rich arsenical copper is probably due to the molecular sluggishness caused by iron in most copper alloys.

Summary.—The paper has been divided into three sections, neither of which can claim to represent more than an exploratory incursion into the subject, for reasons already set forth.

Section I furnishes evidence in favour of the probability that the critical ranges of deformation previously discovered and shown in strength-reduction curves, &c., of cold-rolled copper result from stages of reduction at which the metal was abnormally plastic. It is suggested that during the application of cold-work the metal undergoes alternating periods of hardening and softening, some of the increase in hardness conferred by one or more passes being temporarily lost at a succeeding pass. Specific gravity determinations indicate that the volume changes which take place on continued rolling are negative rather than positive. The increase in volume which sets in at 85 per cent. reduction may correspond to the inception of that permanent disability in the metal which annealing cannot eradicate (see Section II).

Section II affords evidence that annealing at 200 deg. C. for one hour of strips rolled in successive passes from 18 per cent. to 98 per cent. reduction produces unmistakable softening in all strips rolled beyond 40 per cent. reduction. The most severely worked strips show the greatest amount of softening. At 250 deg. C. (1 hour) some of the very severely rolled strips appear to be completely annealed, in the sense that the tensile strength has fallen to, or lower than, that of the original unrolled bar. Accelerated softening sets in at about 45 per cent. reduction, the degree of softening increasing with severity of reduction. A series of test-pieces taken from the axis of the strips undergoes softening to a greater extent than a series taken from near the edge, thus confirming the results obtained from tests on the strips as rolled, viz., the existence of a greater intensity of strain at the centre than at the sides. At 300 deg. C. (1 hour) the acceleration of rate of softening commences at about 26 per cent. reduction, but between 50 per cent. and 93·5 per cent. reduction the annealed strips are progressively stronger. At 93·5 per cent. reduction a rapid decrease sets in. At 350 deg. C. the increase of strength conferred by rolling has been almost entirely removed.

Strips beyond 50 per cent. reduction are progressively stronger up to approximately 90 per cent. reduction, at which point a rapid decrease sets in. At 750 deg. C. (30 minutes) all strips up to 80 per cent. reduction have lost all the increase of strength conferred by rolling. Between 80 per cent. and 90 per cent. reduction a little of the conferred strength has been retained, the maximum strength being at 87 per cent. reduction. The rapid decrease which sets in at this point is progressive up to 98 per cent., reaching abnormally low values from 95 per cent. to 98 per cent. reduction. Air-annealed thin specimens are weaker than "close-annealed" specimens, probably owing to incipient "burning." Yield point and scleroscope hardness determinations confirm the observations above recorded, although concordant results were not so readily obtained. Hardness-temperature curves show that the softening range of temperature is lower the greater the deformation, but there is no reliable evidence that the range is appreciably narrowed.

Section III deals with the low-temperature annealing of copper-rods of varying composition, which have been reduced 60 per cent. in area by cold-drawing. Under the annealing conditions the "tough-pitch" arsenical rods retain their strength practically unimpaired up to 300 deg. C., whereas the "tough-pitch" electrolytic rod has undergone considerable loss of strength. The arsenic content of the former rods varies from 0·36 per cent. to 0·52 per cent., and the oxygen content from 0·026 per cent. to 0·06 per cent.; that of the electrolytic specimen being 0·089 per cent. This variation has little or no influence on the results. "Tough-pitch" arsenical rods containing silver (0·29 per cent.) have a slightly higher annealing temperature than the silver-free rods. The substitution of iron for oxygen in arsenical copper appears to retard the rate of softening, the softening range of temperature being wider than in the case of the "tough-pitch" rods. With high arsenic (0·69 per cent.) and high iron content (0·43 per cent.), the commencement of softening has started at 300 deg. C. but proceeds more slowly than any of the others, only entering the region of rapid recrystallization at 420 deg. C.

The author desires to express his sincere thanks to the following gentlemen: Mr. W. B. Shurrock, for assistance in the preparation of specimens: Mr. H. Lowndes (United Wire Works, Limited), for giving facilities for the drawing of rods; Dr. C. H. Walter (Birmingham Gas Department), for giving facilities for special annealing; and Mr. A. Thomas, for assisting with the whole of the testing.

CATALOGUES.

Electric Fuses.—Safety fuses of the cartridge type are listed with prices in a leaflet catalogue received from the Société Industrielle D'Electricité (France), whose London office is at 25, Queen Anne's Gate, Westminster, S.W. 1.

Case-hardening Compound.—Messrs. Stockton and Bunn, Limited, 11, Queen Victoria-street, London, E.C. 4, send a catalogue describing the methods of using a case-hardening powder for which they are agents. The powder is made by Messrs. Gregory and Co., Dartford.

Steam Engines, Pumps, &c.—Messrs. Gardier Brothers (Belgium), whose office in this country is at Maritime Buildings, Middlesbrough, send catalogues illustrating excellent examples of steam engines, pumps and air compressors which they are offering to deliver at very low prices.

Piling.—A very instructive booklet on concrete piles formed by driving in a steel tube and filling it with concrete is to hand from Messrs. J. and W. Stewart, 12, Berkeley-street, London, S.W. 1. The piles are tapered, and the whole process of driving is illustrated in the booklet.

Screw Grinding.—Particulars of a screw thread grinding attachment for lathes, comprising electrically-driven grinding wheels, pitch varying gear and gauging block are described in a catalogue received from the Precision and Thread Grinder Manufacturing Company, 1, South Twenty-first-street, Philadelphia, U.S.A.

Wood Lathing for Building Construction.—A system of wood lathing joined into continuous lengths and supplied in rolls ready for fixing has been made a special product of the Weston-Reuter Company, Limited, 61, Grace-church-street, London, E.C. 3. The laths are strung on galvanised wires pitched about 9 in. apart. The catalogue shows details of construction and many applications to building work.

Electrical Instruments.—A catalogue of instruments received from Messrs. Nalder Brothers and Thompson, Limited, 97, Dalston-lane, London, E. 8, includes ammeters and voltmeters, power factor meters, rotary synchronisers, relays, frequency meters, insulation testing sets, and leakage indicators for direct and for alternating currents. Each instrument is illustrated, and clear descriptive text is included.

Small Steam Engines.—A catalogue of fixed steam engines, received from Messrs. Marshall, Sons and Co., Limited, Gainsborough, deals with ten sizes ranging from 4½-in. to 13-in. single cylinders, in both the horizontal and vertical types. These engines are suitable for factory drives, electric lighting, and general purposes, and especially for Colonial work. If required, the smaller vertical sizes can be mounted on a four-wheeled truck with a vertical boiler, making a complete portable power unit. These engines are standardised, and are made to stock for immediate delivery.

BALL-HAMMER FOR HARDNESS TESTING.—The Graven ball-hammer for hardness-tests consists of a steel cylinder, about 1¼ ft. long, containing a helical spring which is compressed when the piston is pressed by hand against the surface to be tested. When compression has attained a certain degree, which can be adjusted by turning a screw cap at the closed end of the cylinder, the piston is jerked forward and the steel ball, 10 mm. in diameter, fixed at its extremity, is driven into the material. The diameter of the impression is measured as in Brinell testing.

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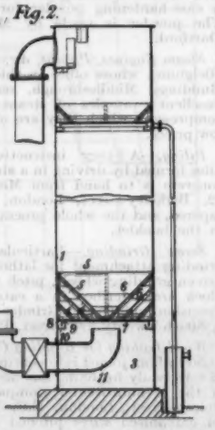
GAS ENGINES, PRODUCERS, HOLDERS, &c.

168,668. J. K. Fraser, Glasgow. Gas Scrubbing and Washing Apparatus. (2 *Figs.*) June 5, 1920.—Gas scrubbing and washing apparatus, according to this invention, comprises a tower 1, fitted with spraying devices 2, and the base 3 of which constitutes a receiver for ammoniacal liquor. Spanning the base 3 is a skeleton structure 4 in which is mounted a series of co-axial hollow perforated frusto-conical elements 5, with which is associated a series of imperforate hollow frusto-conical elements 6, which latter receive the spray from the spraying devices 2 and direct the liquid in the form of a series of cascades towards the receiver 3. Interposed between the elements 6 and the receiver 3 is an imperforate plate 7 of such dimensions as to

Fig. 1.

Fig. 2.



provide at 8 an annular opening for the passage of gas from the receiver end of the tower 1 towards the upper end. Depending from the peripheral edge of the plate is a flange 9 which dips into a well 10 and thus affords a liquid seal. 11 is the gas inlet pipe. In the operation of scrubbing and washing, the ammoniacal liquor is pumped continuously from the receiver 3 to the spraying devices. The liquid passes from the spraying devices 2 into a state of intimate commingle ment with the gas and descends towards the elements 5 in the form of a mist. The liquor passing through the elements 5 is directed over the edges of the elements 6 as a series of cascades through which all the gas to be scrubbed or washed is constrained to pass, the liquid flowing through the liquid seal 10 and thence towards the receiver 3. (*Sealed.*)

LIFTING AND HAULING APPLIANCES.

168,779. E. M. Medway, Deptford, London, E. C. Smith, Deptford, London, and A. S. Medway, Deptford, London. Lifts. (2 *Figs.*) September 1, 1920.—According to this invention, the cage door or gate of a lift is provided with a clutch, the jaws of which are automatically opened when the lift is running and are automatically closed to engage with a ramp on a landing door when the controller is in the "off" position, that is, when the lift is at rest. 1 is the top of a lift having three sliding doors 2, 3, 4. 5 are the walls on a landing having three landing doors 6, 7, 8. On the lift door 2 is mounted a solenoid 9, the core of which is connected with one arm of a bell crank lever 12. The other arm of the bell crank lever 12 is connected to a lever 15 pivotally mounted on the door 2. 17, 18 are jaws which are pivotally mounted on the door 2. To the jaws 17, 18 are pivotted toggle levers 20, 21, whose ends are connected to the end of the lever 15. 23 is a ramp fast with the landing door 6. Mounted on the solenoid 9 is a spring actuated plunger 24 which tends to maintain the bell crank lever 12 in the position shown in the drawings. The solenoid 9 is connected to the controller (not shown) in such a manner that current is automatically cut off from the solenoid when the controller is in the "off" position, that is, when the lift is at rest. 25 is a small motor mounted on the lift cage 1 and adapted to drive an endless belt 26 which passes over a pulley 27 mounted on the other end of the lift 1. In Fig. 2 the pulley 27 has been omitted for the sake of clearness. The belt 26 is provided with a pair of stops arranged one on either side of a lug 29 fast with the door 2. Preferably the wiring is so arranged that when the controller is in the "on" position, no current can pass to the motor 25, and that when the current is supplied to the motor 25 no current can pass to the motor (not shown) for operating the lift 1. The doors 2, 3, 4, 6, 7, 8 are provided with lugs 30. Preferably the landing door 6 is provided with ratchet teeth 31 with which teeth on one arm of a T-lever 32 can engage, there being a lever 32 provided on each landing. 33 is a spring-actuated plunger engaging the other arm of the T-lever 32. On the side of the cage 1 is a ramp 34 which engages the stem of the T-lever 32 and disengages the teeth on the T-lever 32 when the lift 1 is opposite a landing. The operation of the mechanism is as follows: When the lift is opposite a landing the parts are in the position shown in the drawings, current is cut off from the solenoid 9 and the spring plunger 24 acting on the bell crank lever 12 has moved the toggle levers 20, 21, into line, thus causing the jaws 17, 18 to engage the ramp 23

Fig. 1.

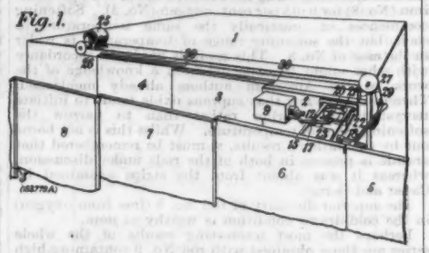
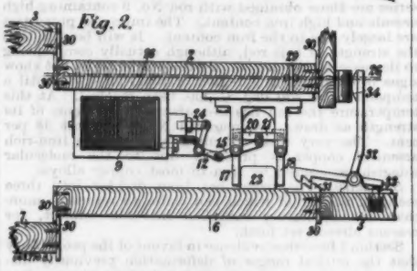


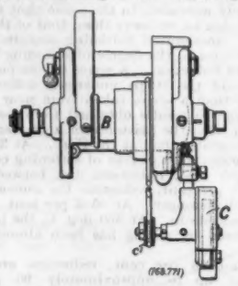
Fig. 2.



on the door 6, at the same time the teeth on the T-lever have been moved out of engagement with the teeth 31. If current be now supplied to the motor 25, the door 2 will be opened through the medium of the stop acting against the lug 29; as the clutch jaws 17, 18 are in engagement with the ramp 23 the door 6 will move together with the door 2. When the doors 2 and 6 have moved a distance equal to their width, stops 30 will engage the ends of the doors 3 and 7, and the doors 2 and 3 and 6 and 7 will move together, and so on. Preferably the current is automatically cut off from the motor 25 when the doors 4 and 8 are fully open. In order to close the doors 2, 3, 4, 6, 7, 8, the motor 25 is reversed. As soon as the controller is moved to the "on" position the solenoid 9 is energised, the bell crank lever 12 is thereby rocked and the toggle levers 20, 21 are moved out of line and the jaws 17, 18 opened in which position there is no danger of the said jaws 17, 18 fouling the ramps at the different landings. (*Sealed.*)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

168,771. A. Drummond, Guildford, and G. L. Norman, Guildford. Tool-Grinding Attachments. (3 *Figs.*) August 19, 1920.—According to this invention, the grinding



wheel C is mounted in a small carrier adapted to be fitted detachably to the headstock of the lathe, and the grinding wheel spindle is provided with a small pulley e1 driven by a belt from the cone pulley R of the lathe, preferably from the pulley wheel of largest diameter. (*Sealed.*)

168,766. H. F. L. Orcutt, Handsworth, Birmingham, and The Gear Grinding Company, Limited, Handsworth, Birmingham. Grinding Machines. (3 *Figs.*) August 14, 1920.—The object of the invention is to provide means for enabling the proper position of the grinding wheel relative to the trimming tools in the trimming operations to be readily obtained, and also, if desired, for preventing accidental starting during the aid operation of the mechanism by which the grinding wheel is reciprocated relatively to the work. In the trimming operation it is essential that the axis of the grinding wheel should be in some predetermined position, *e.g.*, the plane of movement of the trimming tools. To ensure this, a crank disc *e* which actuates the slide *b* is formed with a lateral aperture *f* into which a locking plug *g* can be inserted, the relationship of the aperture and plug being such that they can only be engaged when the axis of the grinding wheel *a* is in the same plane as that in which the trimming tools move, or in some other definite and predetermined position.

Fig. 1.

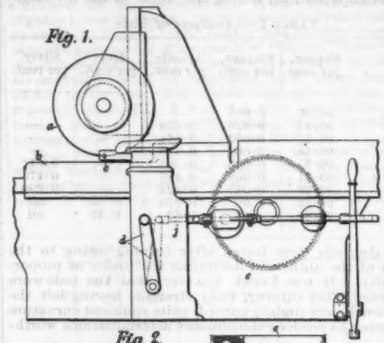
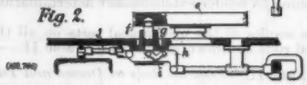


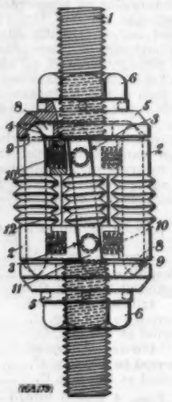
Fig. 2.



In conjunction with the plug *g* is arranged a sliding bar A which is formed with a cam slot *i* for moving the plug into or out of action when an appropriate endwise movement is given to the bar. The latter is connected by a link *j* with the hand lever *d* which controls the starting and stopping of the trimming mechanism. The grinding wheel having been brought into the correct relationship with the trimming tools, the plug is engaged with the crank disc, thereby locking the same. If the wheel is not properly related to the tools the plug cannot enter the crank disc aperture and movement of the lever *d* is resisted. (*Sealed.*)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

168,179. W. Crockatt, Pollokshields, Glasgow. Tube Cleaner. (1 *Fig.*) June 10, 1920.—In a tube-cleaning tool comprising a body part wherein are mounted, between resilient and unyielding but adjustable retaining devices, a number of spindles angularly disposed with respect to the axis of the tool and carrying scaling elements or cutters, the unyielding retaining devices are adapted, according to the present improvements, to effect or admit of a simultaneous and equal adjustment of all the spindles carrying the scaling elements or cutters, either against or under the action of the resilient retaining devices. The tool illustrated comprises a shaft 1 having collars 2 wherein are slots 3 angularly disposed with respect to the axis of the shaft 1 and having recesses 4 in the bases thereof, each slot in one collar being in alignment with an associated slot in the other collar. The shaft 1 is screwed exteriorily of the collars 2 and nuts



5 and 6 are mounted at each end thereof, the former having annular grooves 8 in the faces opposed to the collars 2. The grooves 8 have conically inclined outer walls 9. Springs 10 are mounted in the recesses 4 and spindles 11 having tapered or rounded ends and carrying rotatable scaling cutters 12 are mounted in the slots 3, where they are retained in operative position between the springs 10 and walls 9. Equal adjustment of the spindles 11 to adapt the tool for use in tubes of different diameters is effected simultaneously and at a single operation by adjustment of either or both of the nuts 5. By reducing the distance between the nuts 5, the spindles 11 are constrained into the slots 3 against the action of the springs 10; whilst by increasing the distance between the nuts the spindles 11 are allowed to expand in the slots 3 under the action of the springs 10. (*Sealed.*)

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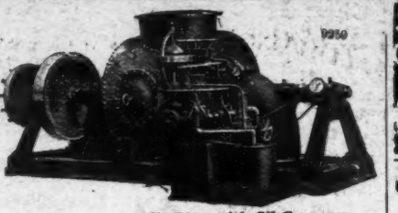
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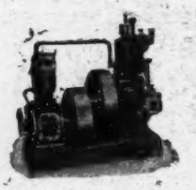
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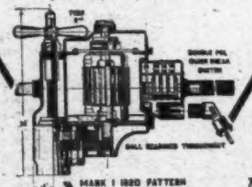
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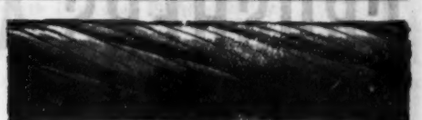

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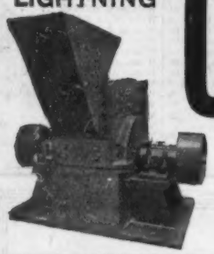

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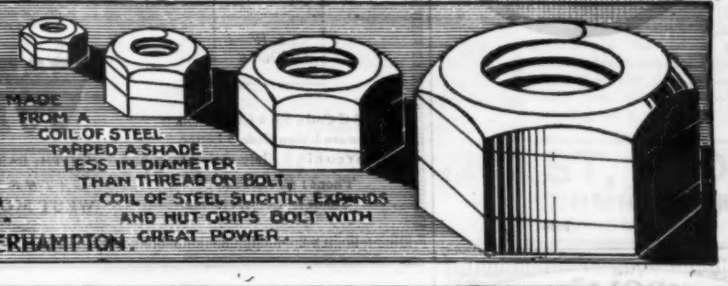

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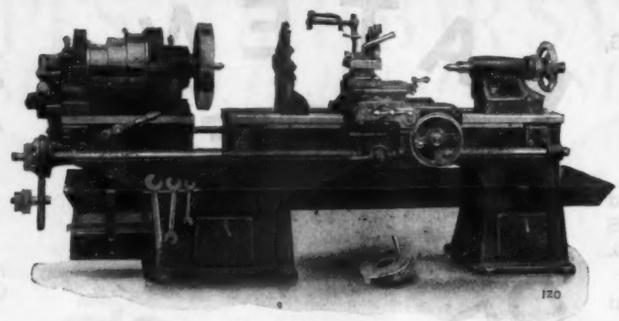

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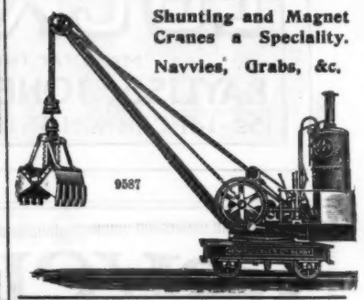

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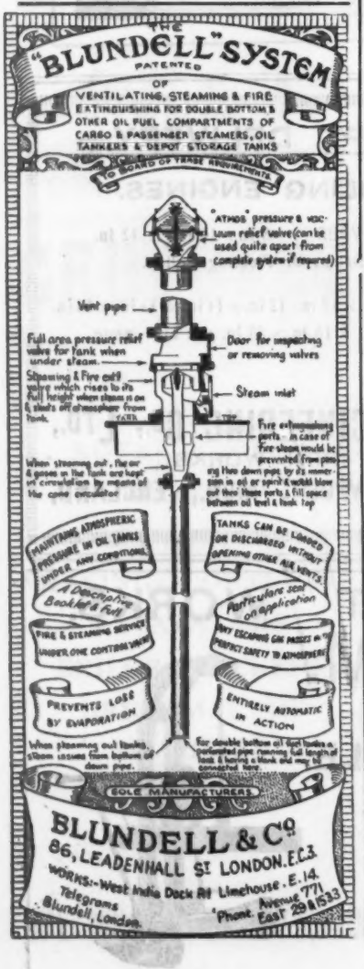
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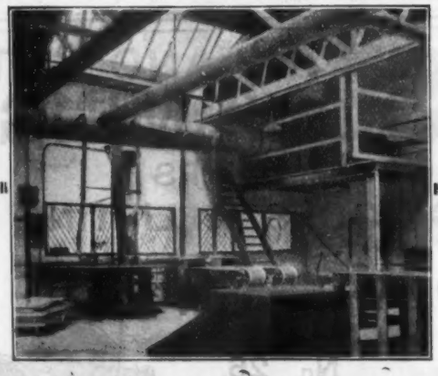

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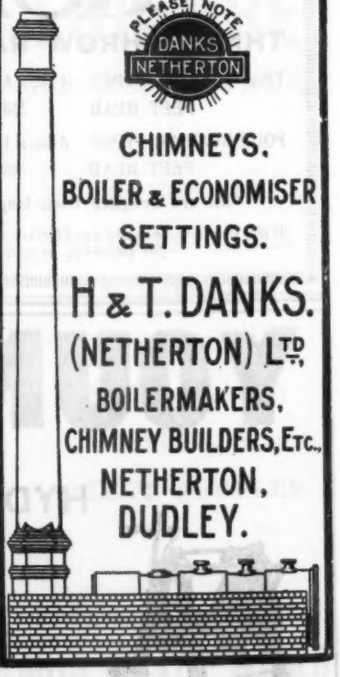

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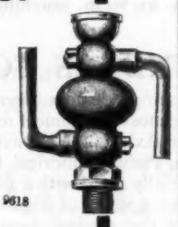

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NEW DESIGN.

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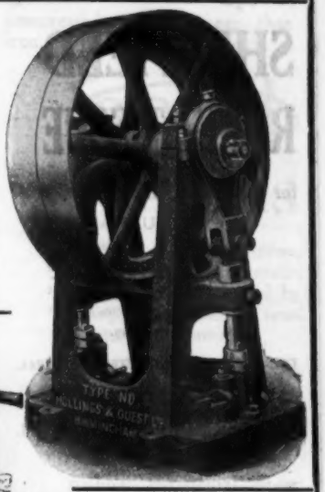

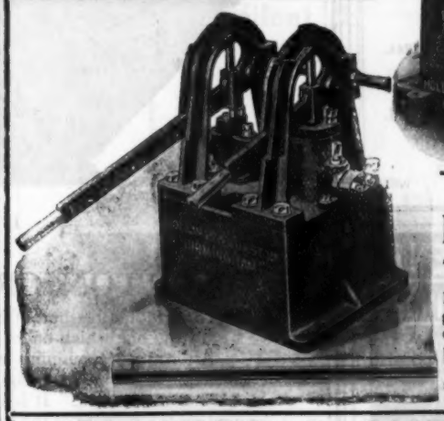

LATEST DESIGN.

Hand Hydraulic Pump.

THE photo shows a set of double plunger Hand Pumps, with a large plunger for getting up the press rams quickly, and a small plunger for putting on the final pressure. They are shown complete, standing on a tank. 9730

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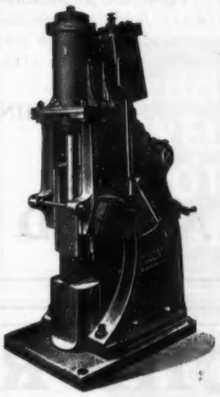

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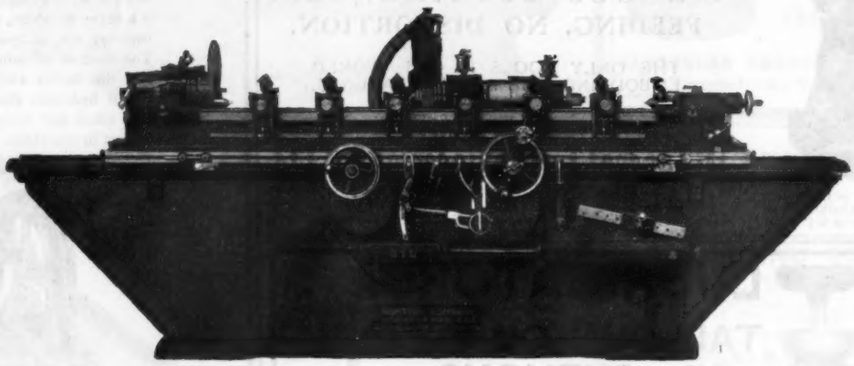

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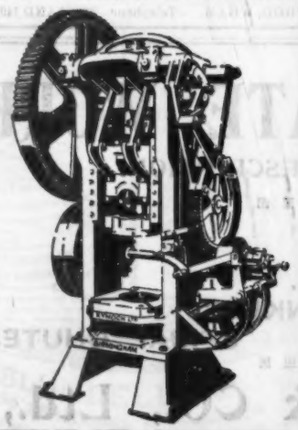

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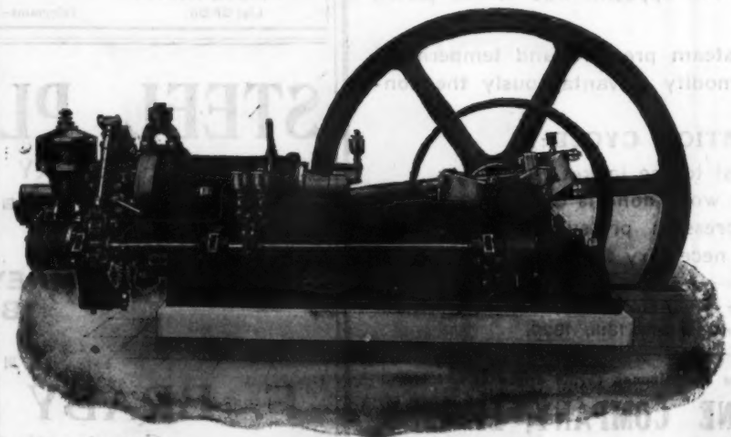

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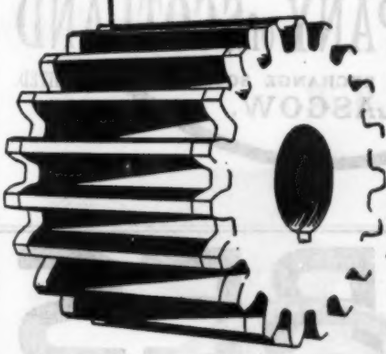

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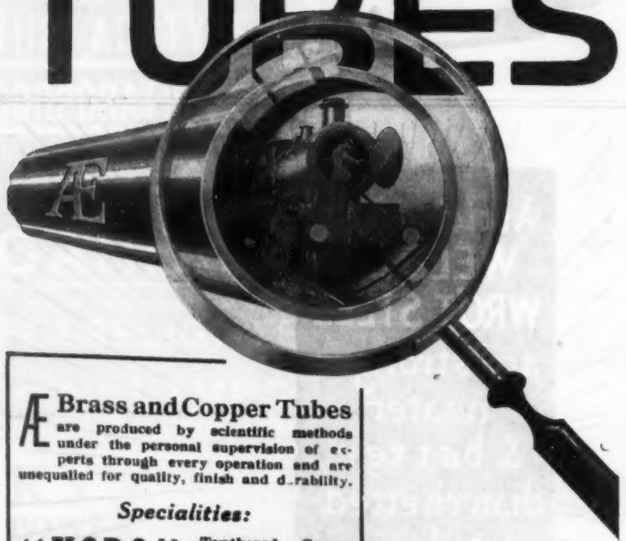

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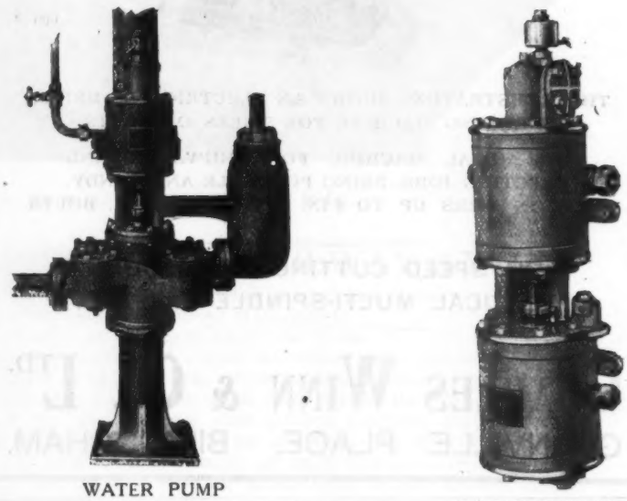

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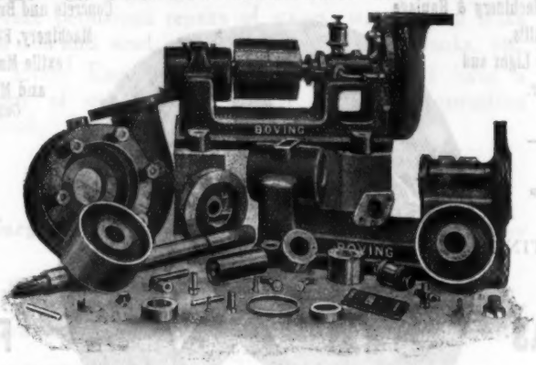

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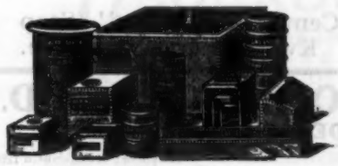

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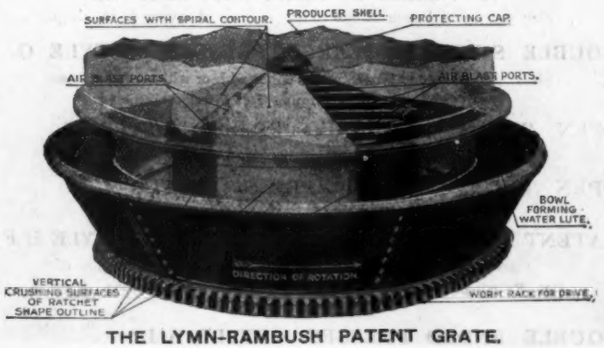

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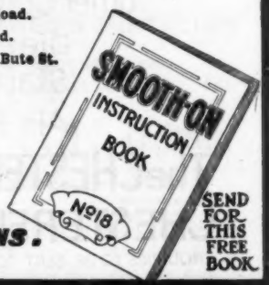

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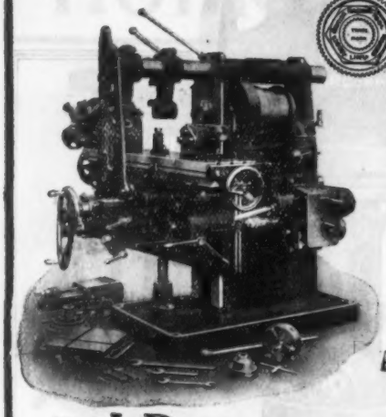

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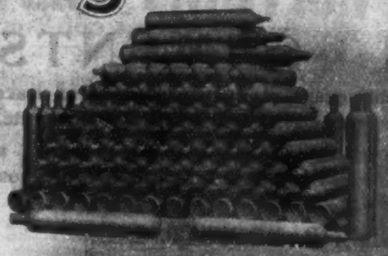

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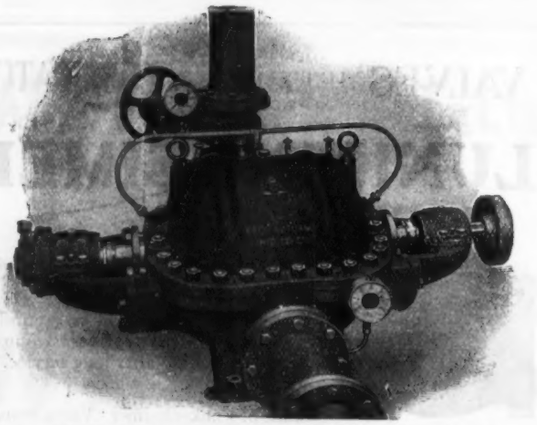

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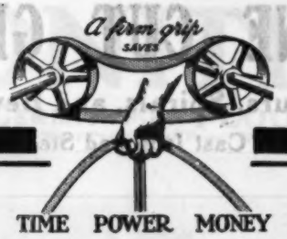

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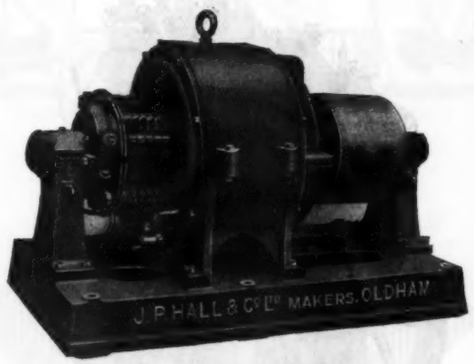

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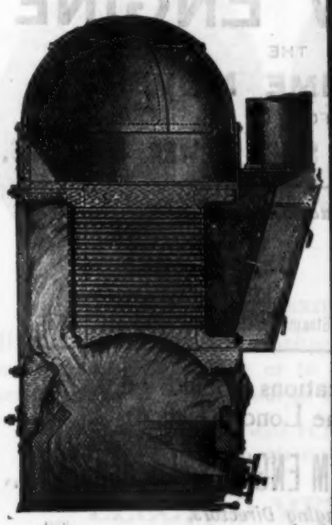

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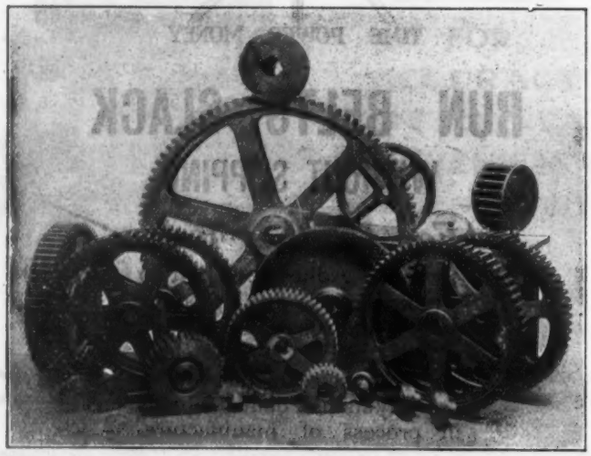

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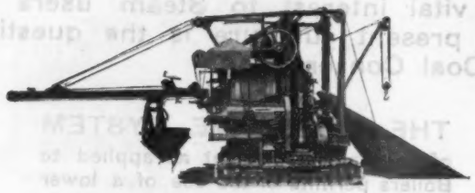

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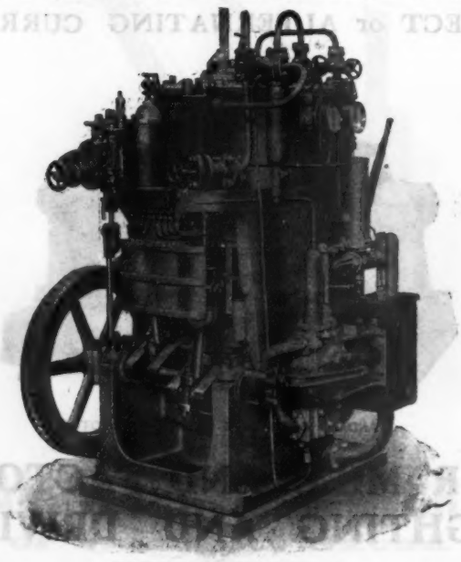

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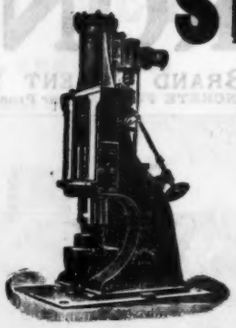

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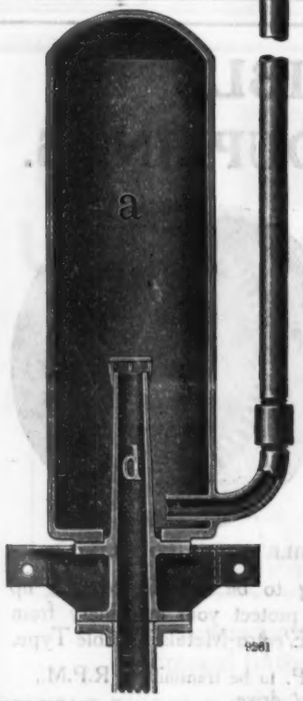

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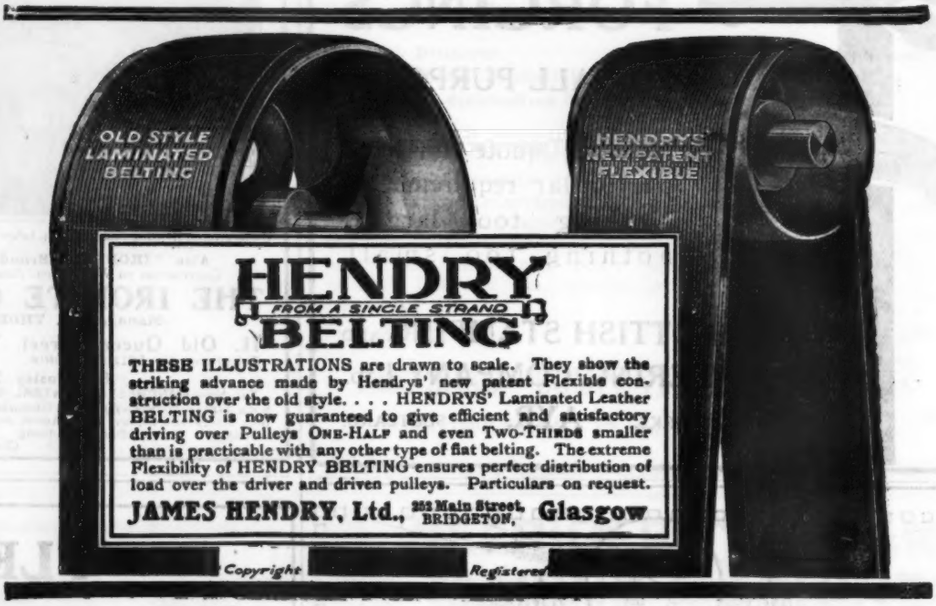

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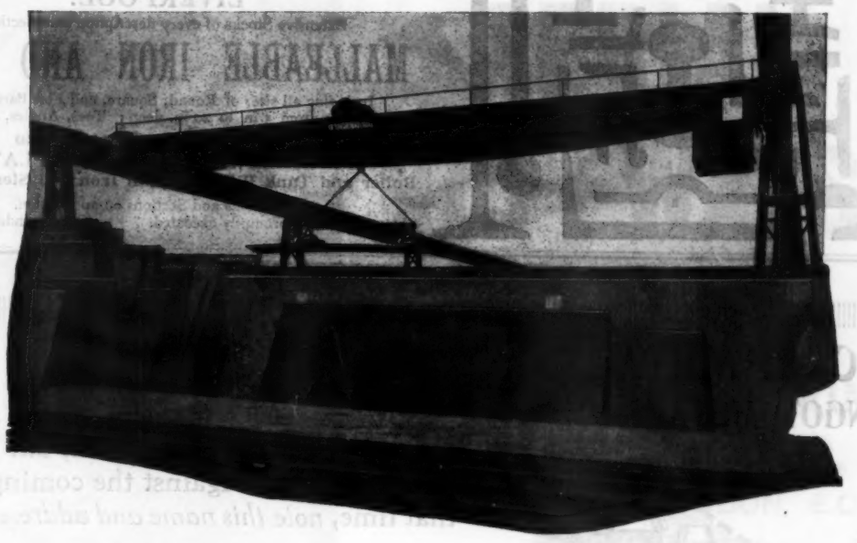

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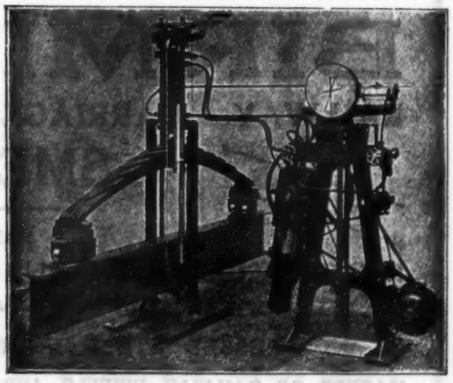

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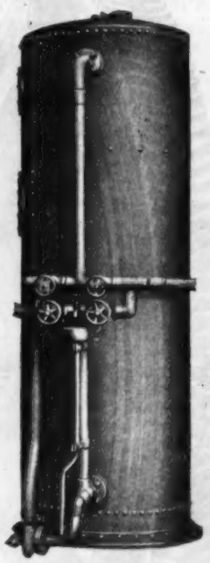

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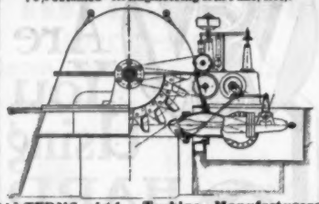

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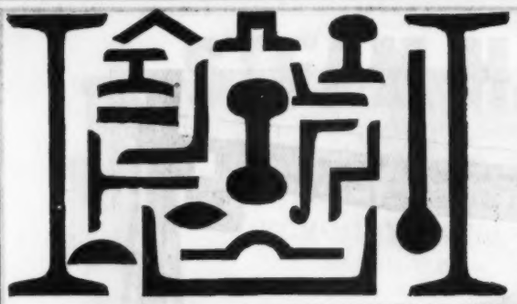

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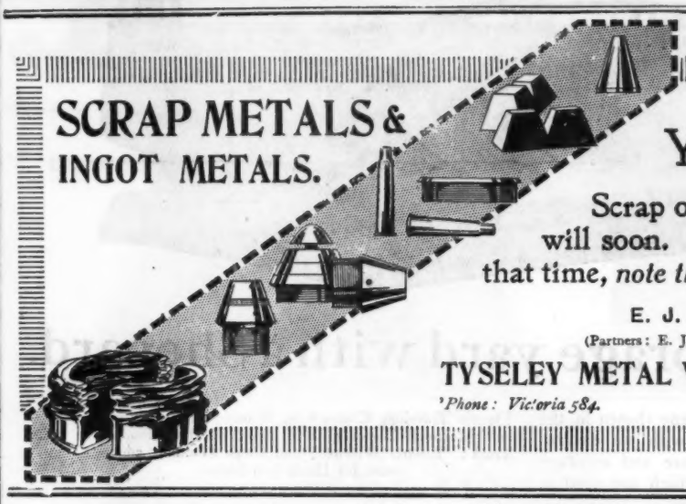

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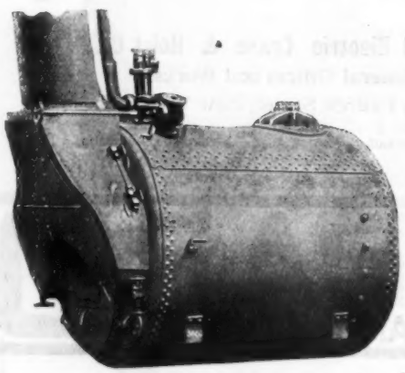

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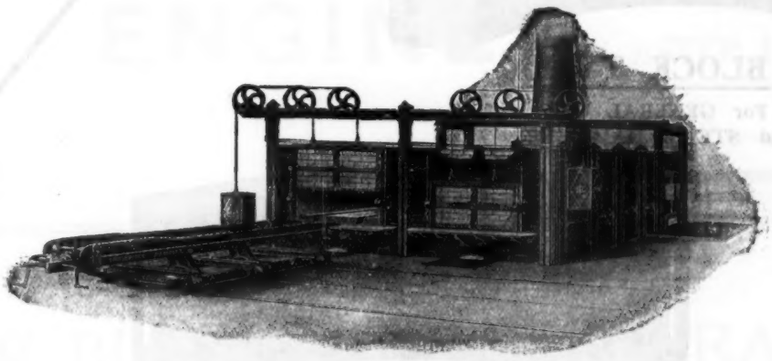

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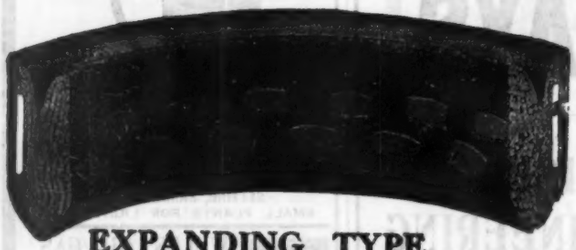

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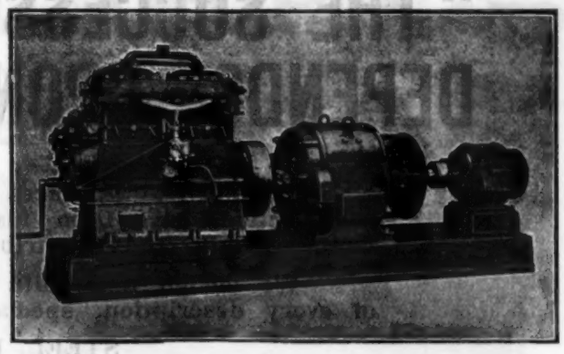

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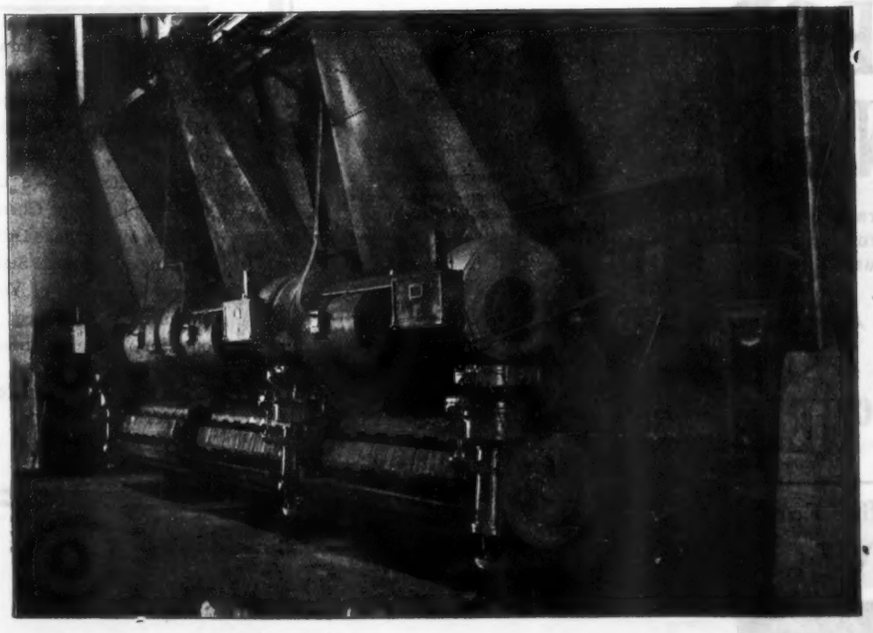

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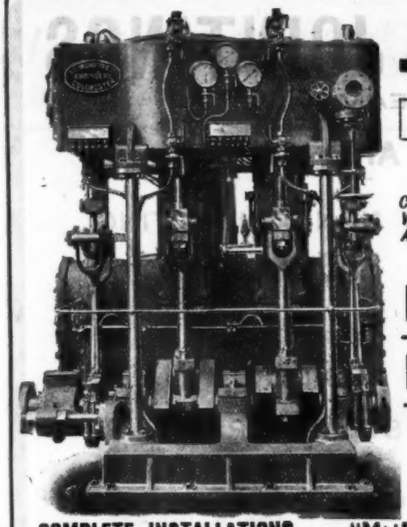

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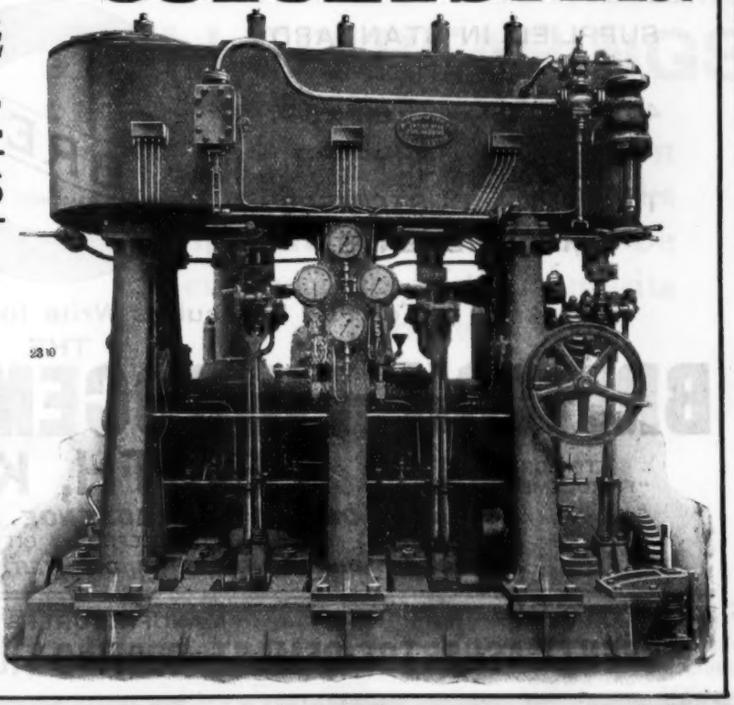

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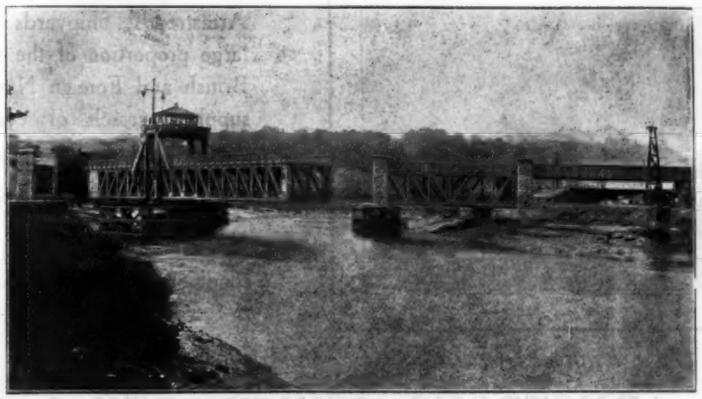

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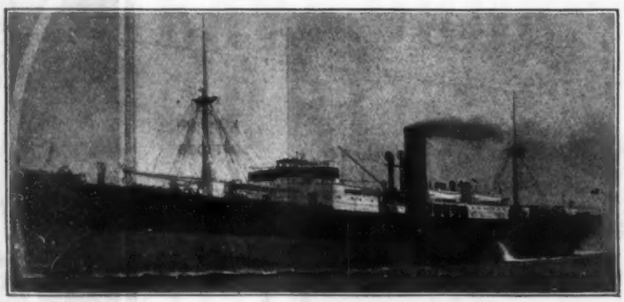

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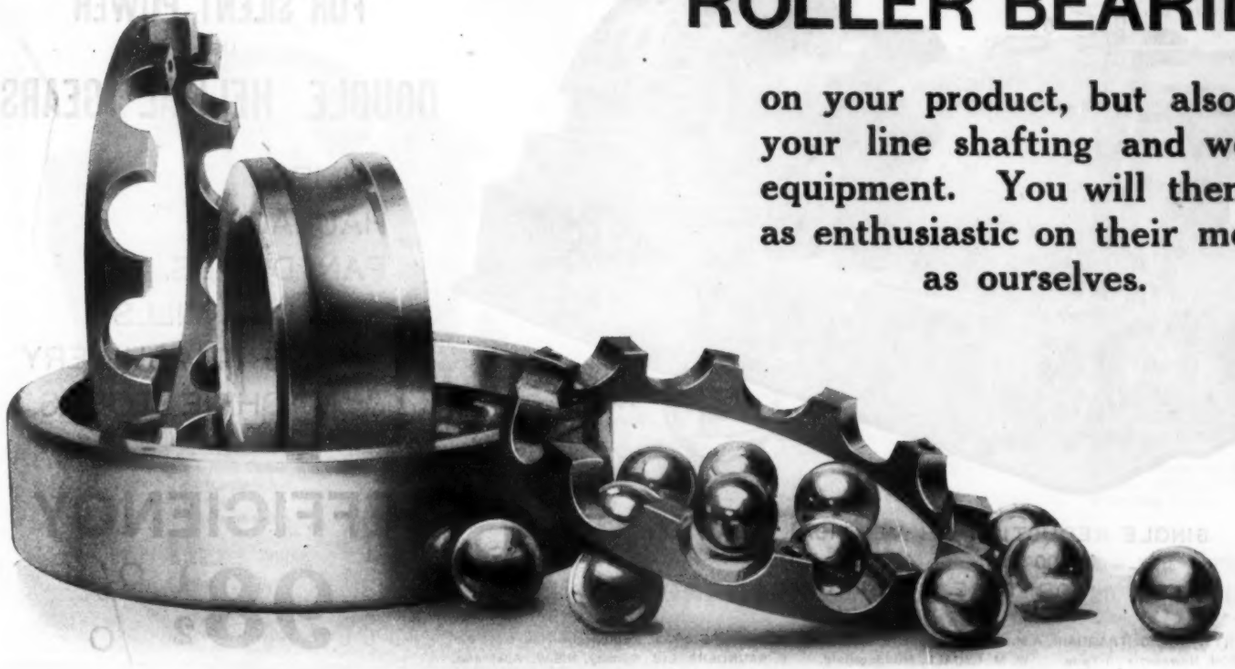

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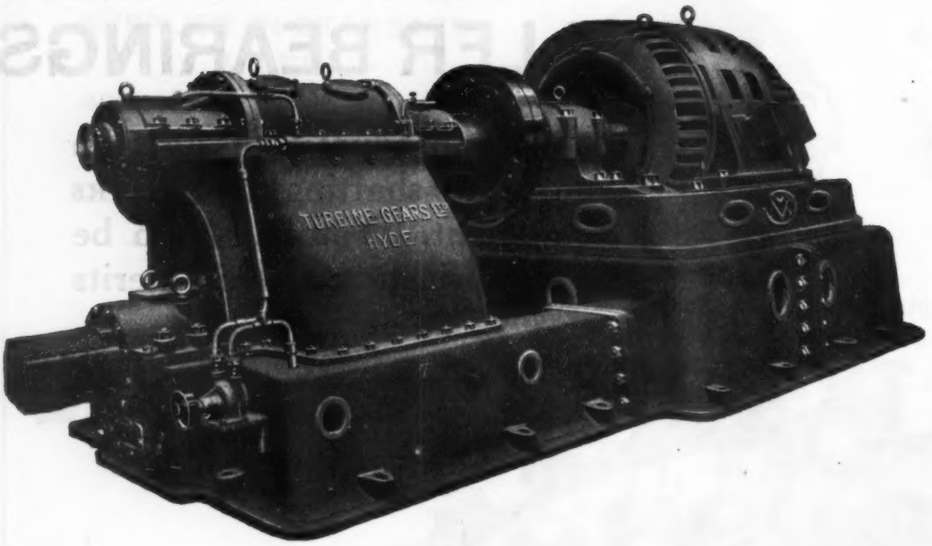

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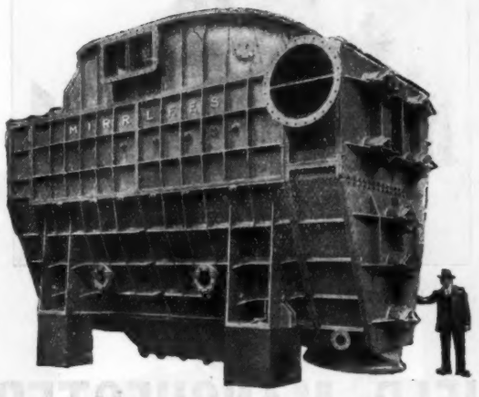

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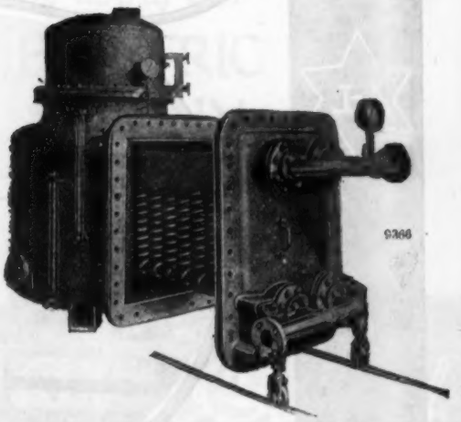

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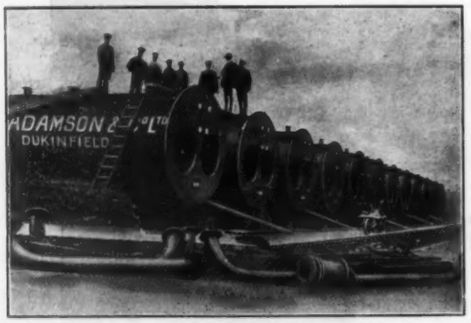

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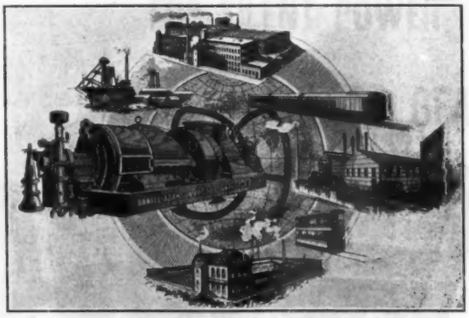

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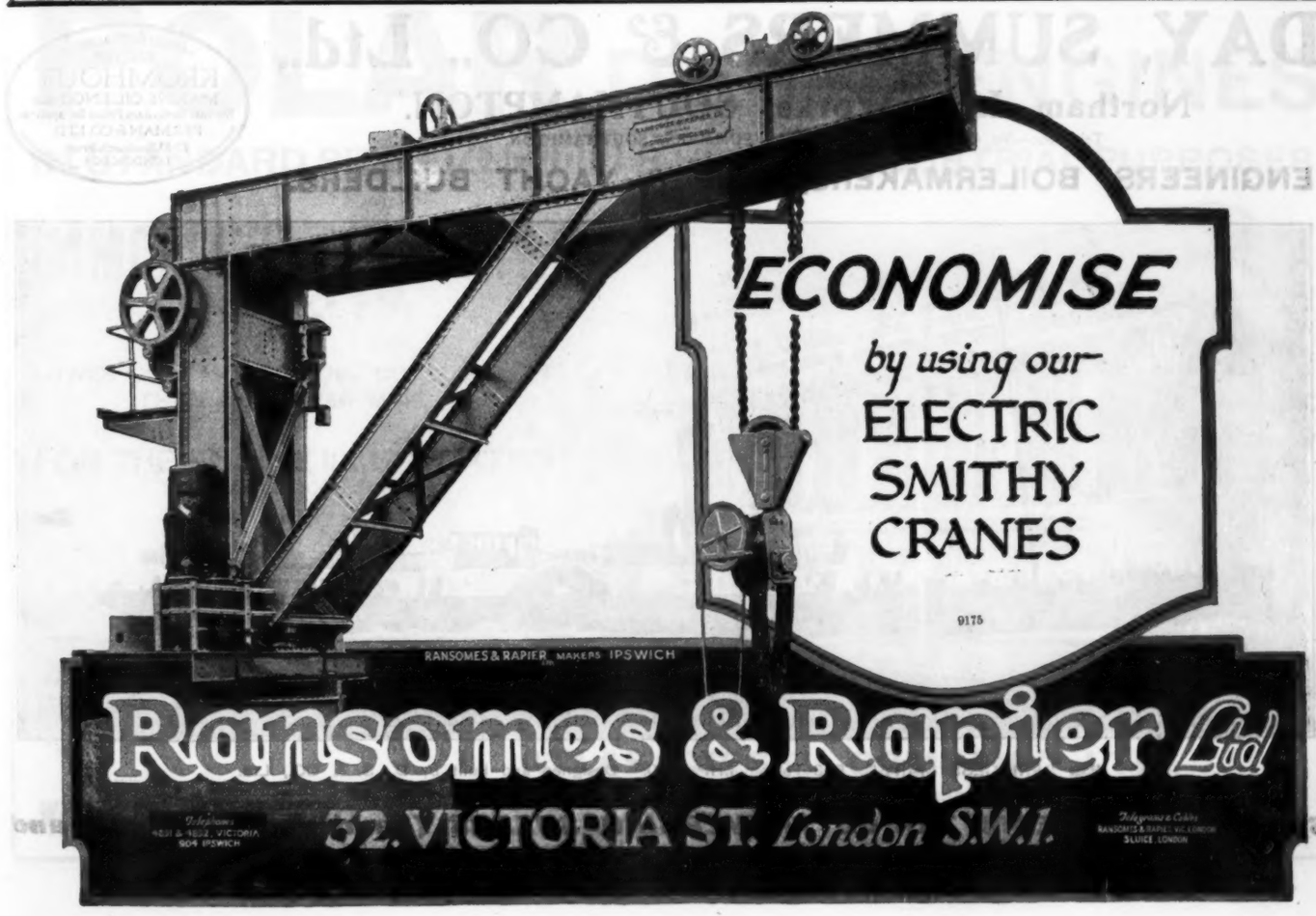

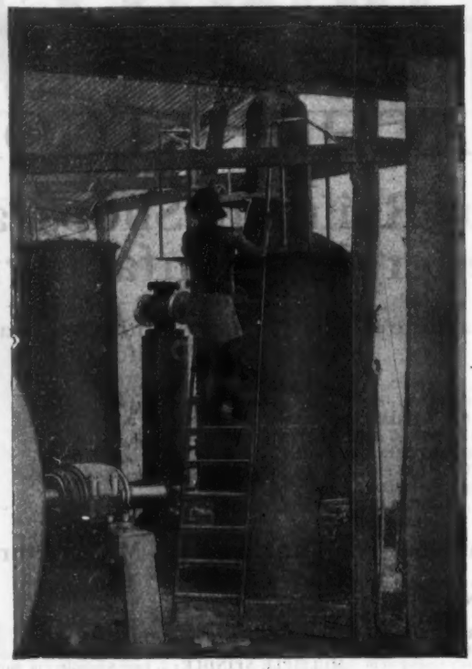

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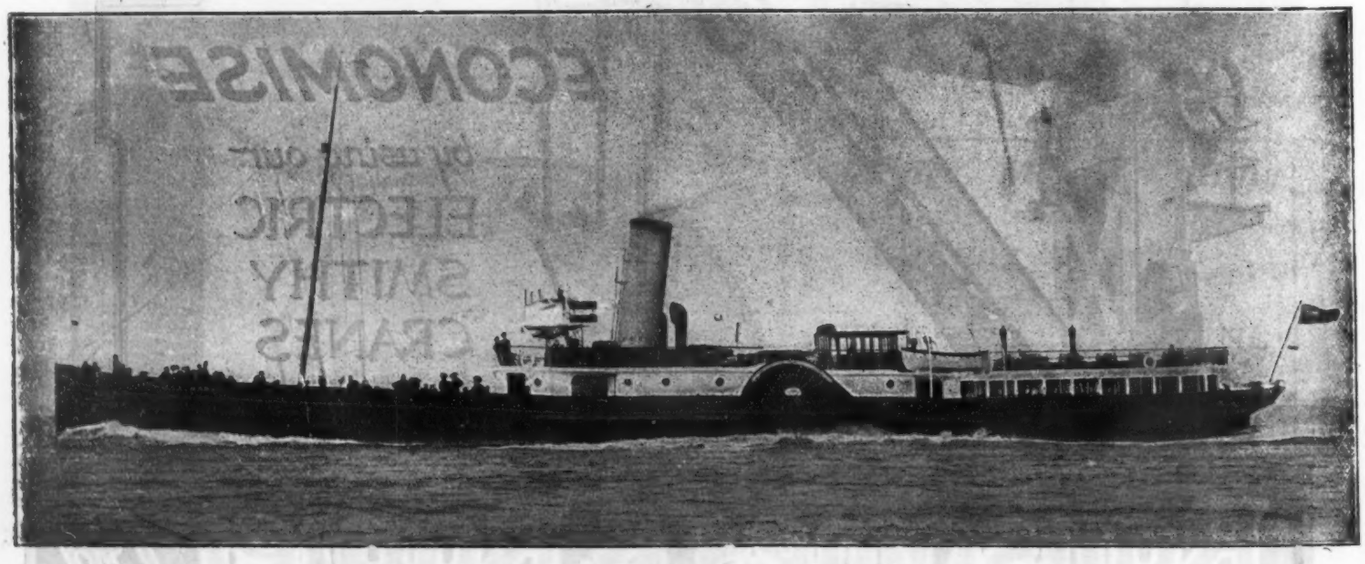

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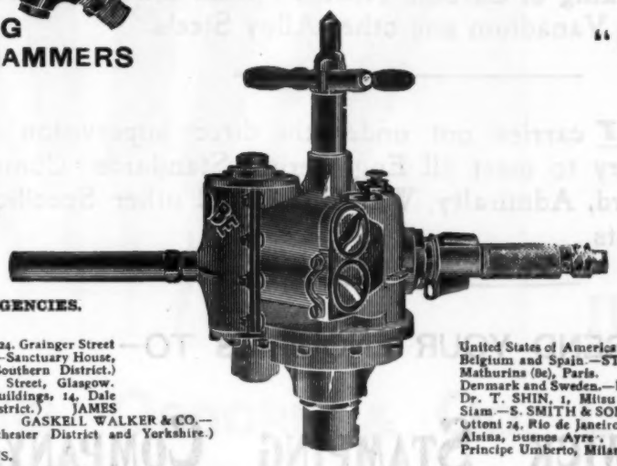

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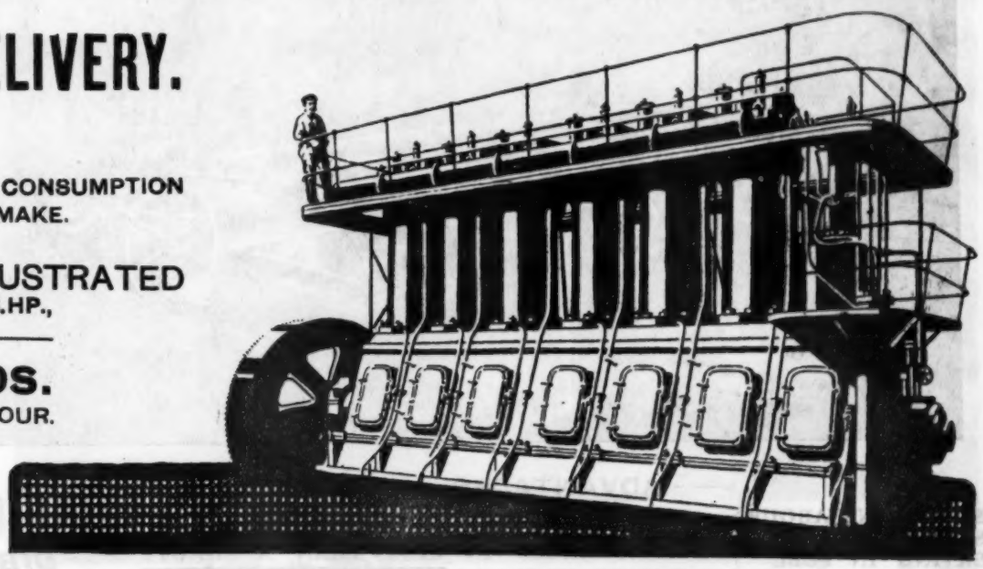

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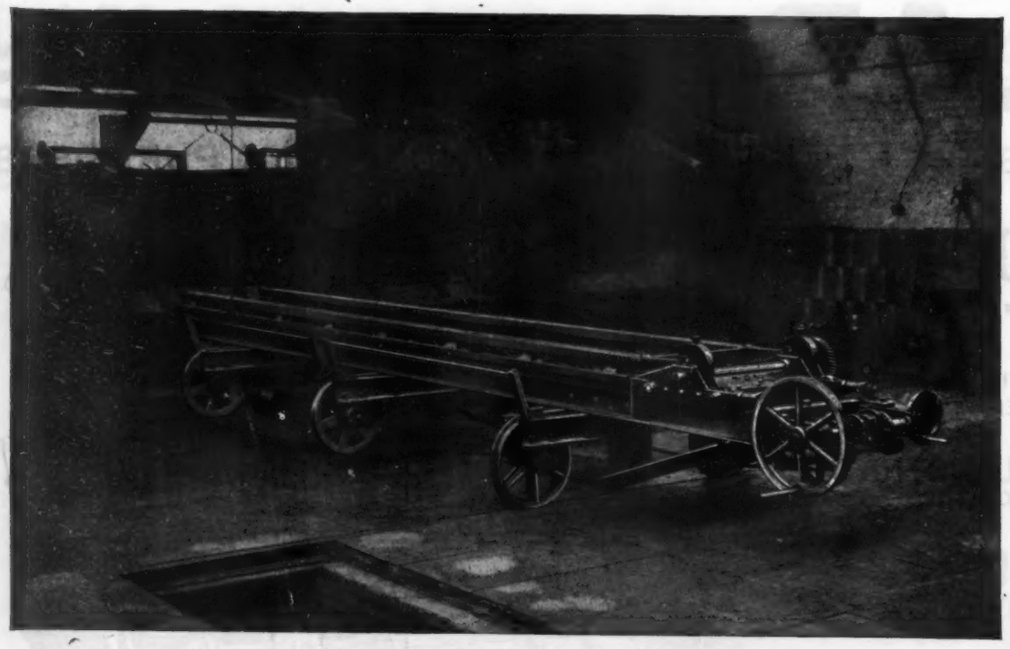

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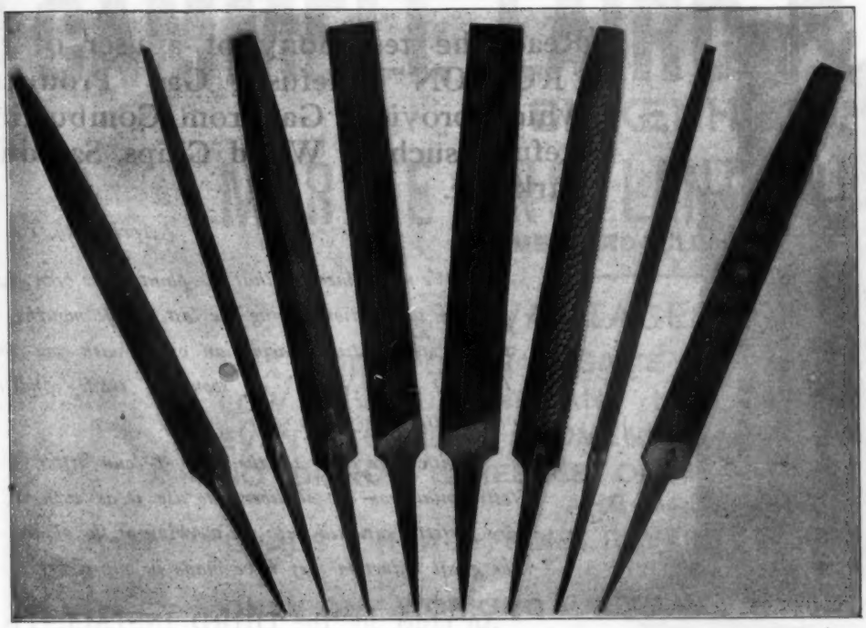

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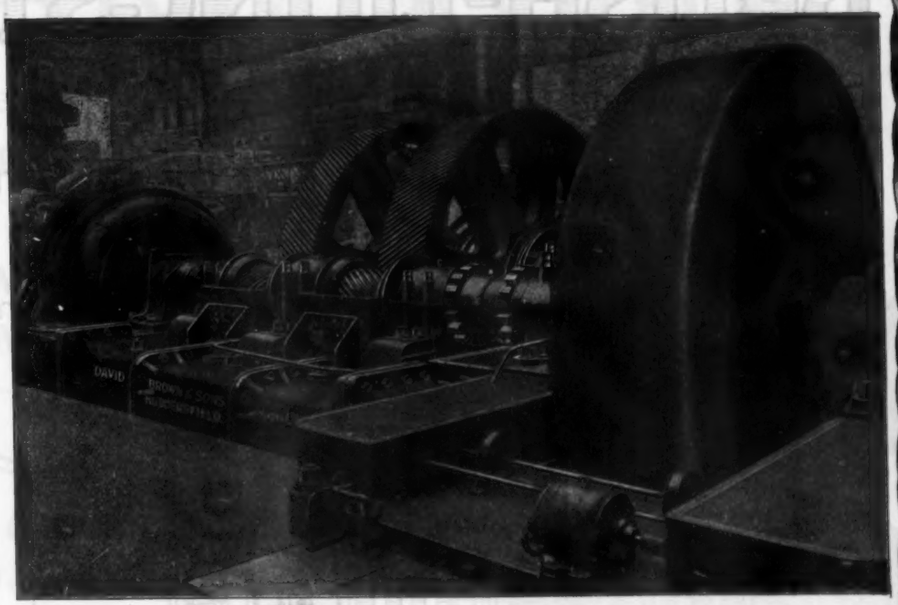

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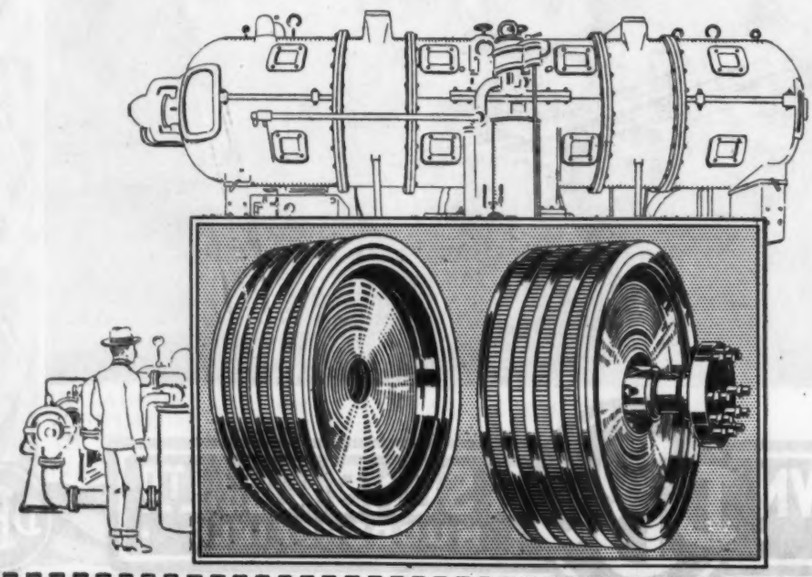

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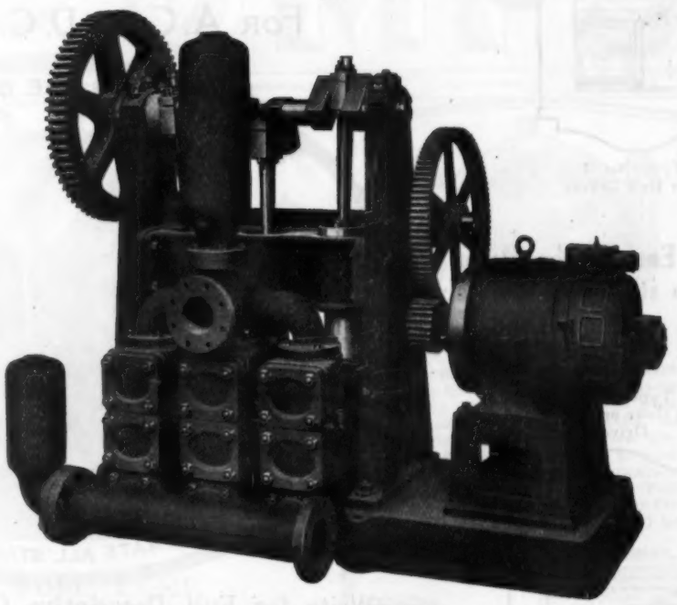

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THE TERRY TURBINE

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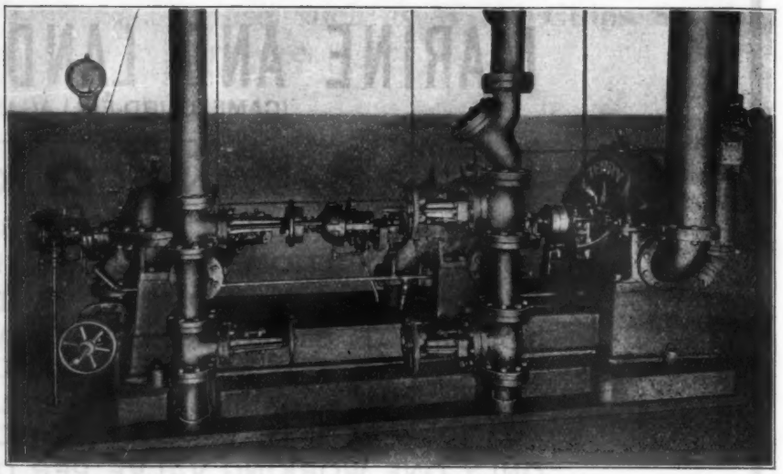

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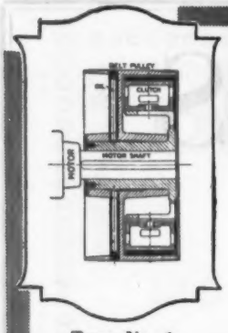

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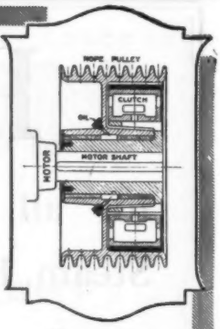

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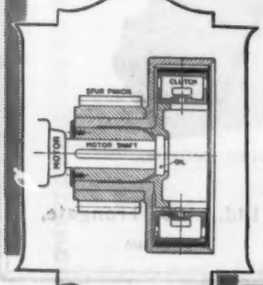

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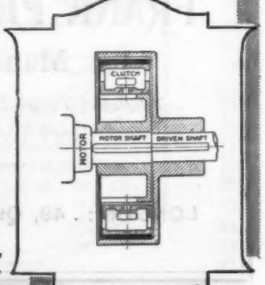

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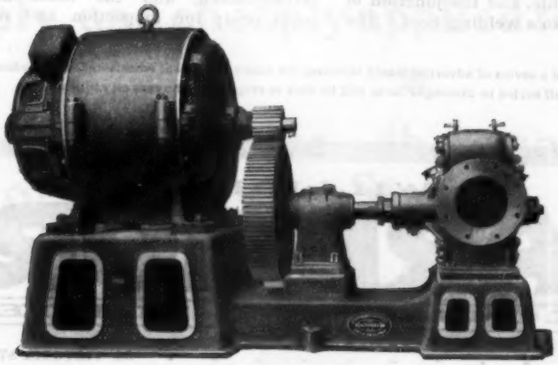

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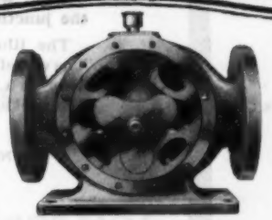

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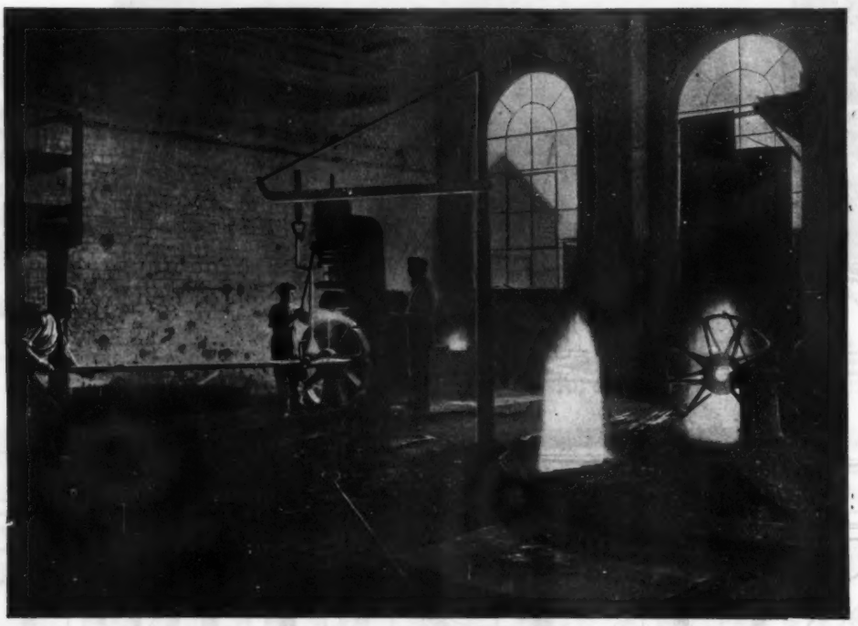

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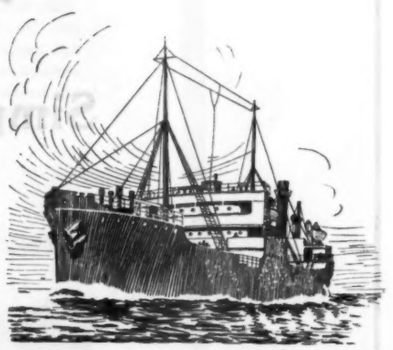

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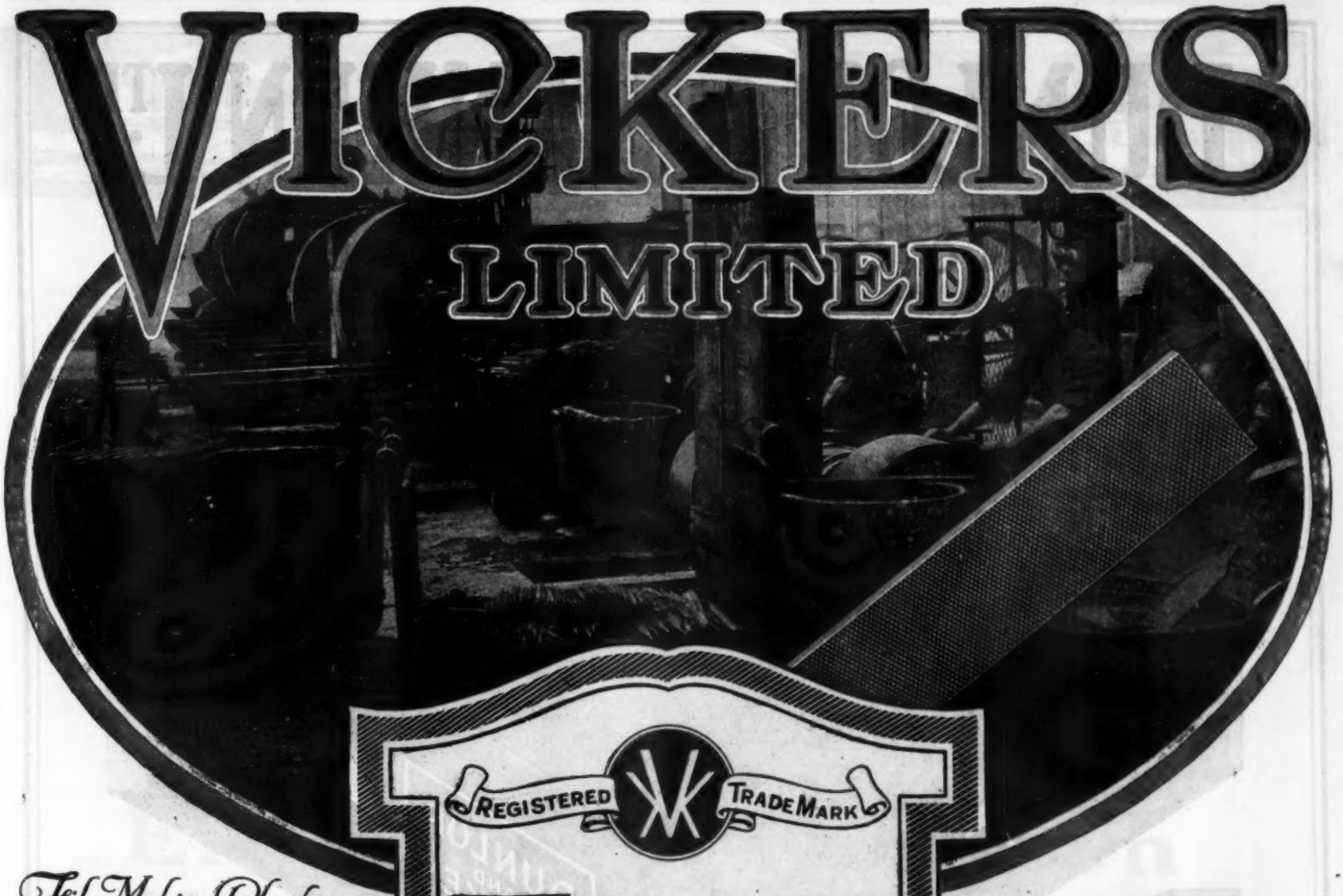

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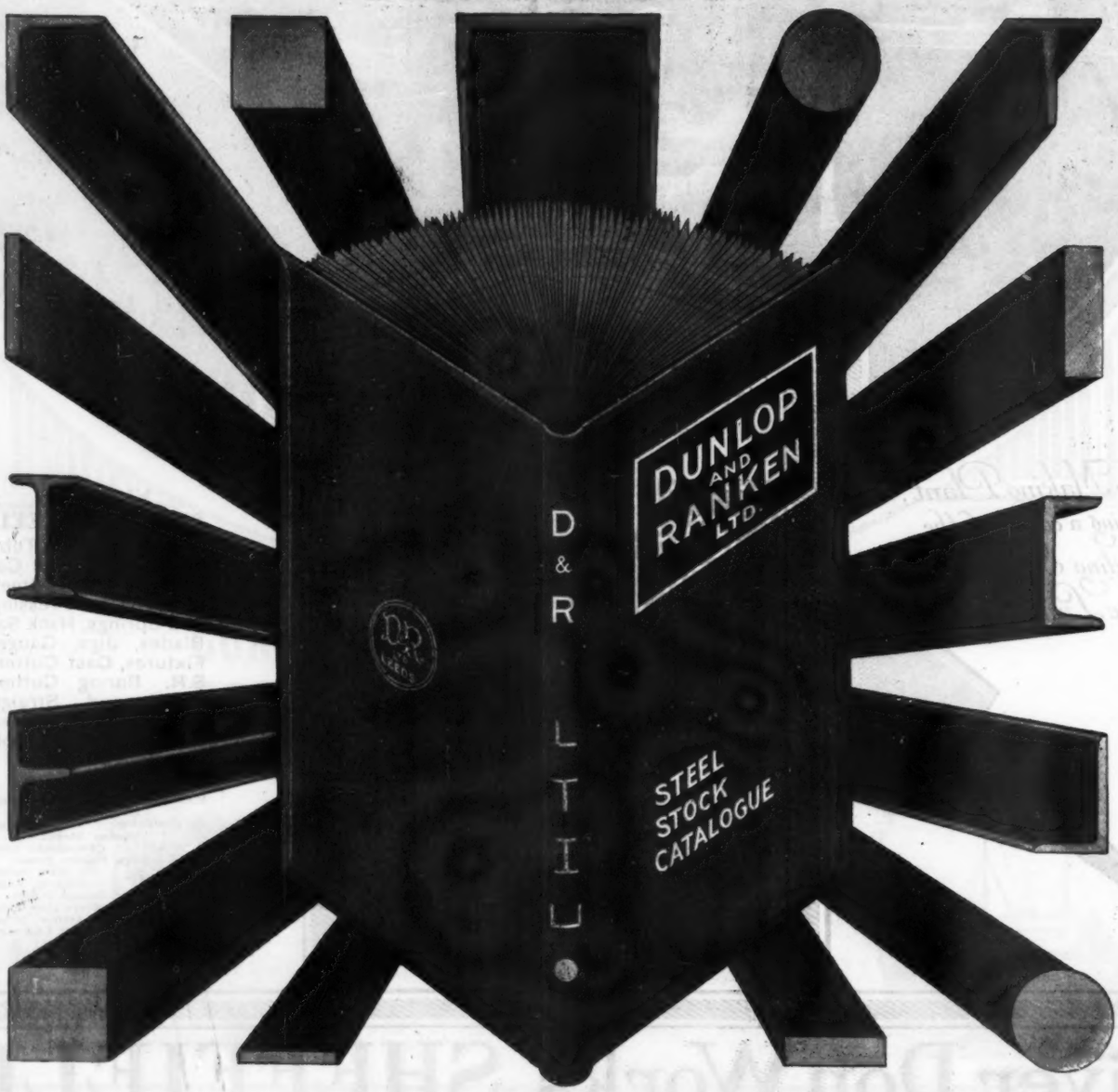

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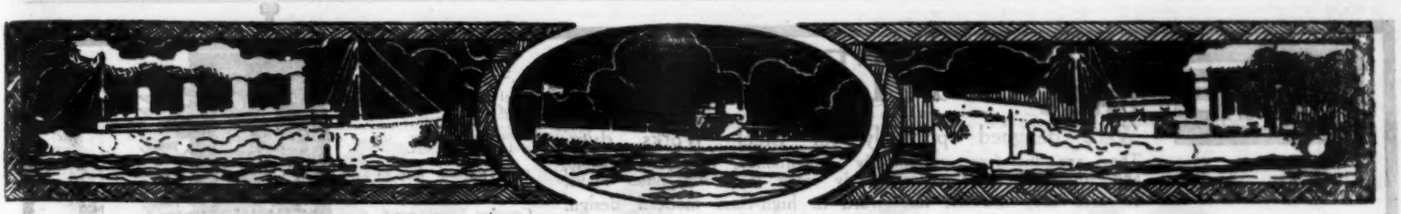

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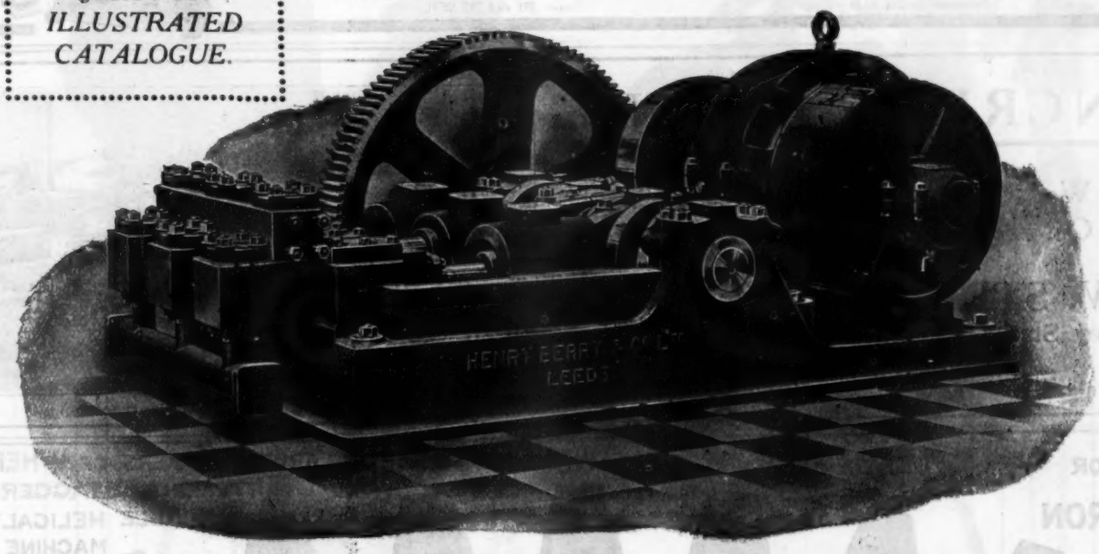

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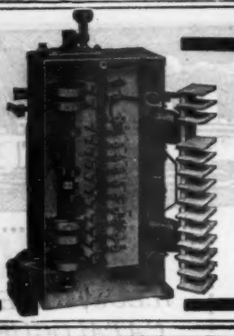

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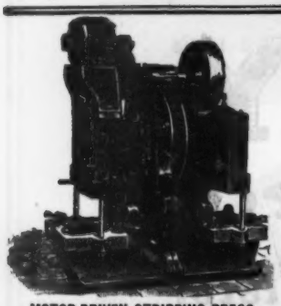

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For Land and Marine Purposes.

Brotherhood Steam Engines and Turbines offer dependable, low-cost power, and embody the specialised skill of many years' experience.

STEAM TURBINES.

Impulse Type, up to 1000 HP. Special types for back pressure work. Automatic bearing lubrication by ring or pump, according to size.

Simple and Compound STEAM ENGINES

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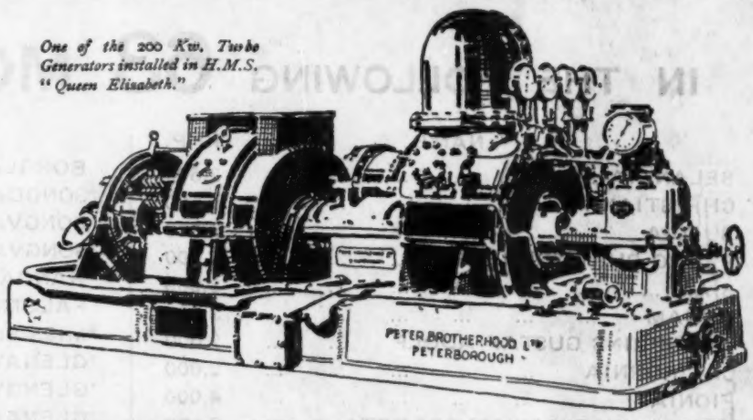
One of the 200 Kw. Turbo Generators installed in H.M.S. "Queen Elizabeth."



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Made in sizes from 15 to 200 HP.

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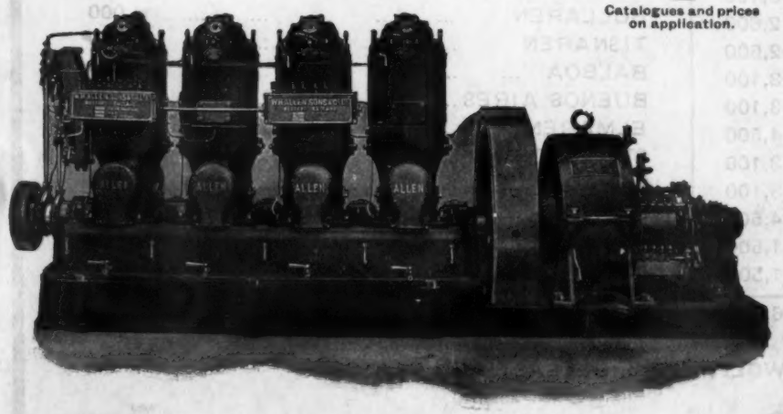

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Heavy Fuel Oil Engine

POWER AT MINIMUM COST.

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It is easy to start and runs unattended for long periods.

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ENGINEERS AND SHIPBUILDERS, COPENHAGEN, DENMARK.

UP TO THE END OF JULY 1921

IN ACTUAL SERVICE

BURMEISTER & WAIN MARINE DIESEL ENGINES

IN TOTAL AGGREGATING 191,290 I.HP.

IN THE FOLLOWING 63 MOTOR SHIPS.

NAME	I.HP.
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CHRISTIAN X	2,500
SUECIA	2,000
PEDRO CHRISTOPHERSEN	2,000
SIAM	3,000
ANNAM	3,000
KRONPRINS GUSTAF ADOLF	2,000
CALIFORNIA	2,600
FIONIA	4,000
KRONPRINSESSAN MARGARETA	2,000
MALAKKA	3,100
TONGKING	3,100
PACIFIC	2,000
PANAMA	3,100
SAN FRANCISCO	2,000
AUSTRALIEN	3,100
COLUMBIA	3,100
CHILE	3,100
OREGON	2,800
PERU	3,100
GEORGE WASHINGTON	3,100
VALPARAISO	2,600
LIMA	2,600
BONHEUR	3,100
ASIA	3,100
AFRIKA	4,500
THEODORE ROOSEVELT	3,100
FORMOSA	3,100
MALAYA	4,500
BRAZIL	1,500
BAYARD	1,500
	86,800

NAME	I.HP.
BORGLAND	2,000
*SONGDAL EX FOLKVARD	1,700
*SONGVAND EX LIDVARD	1,700
*SONGVARD EX LANDVARD	1,700
*KANGAROO	2,250
*FALSTRIA	2,250
*MISSISSIPPI	3,200
*GLENAVY	3,000
*GLENGYLE	3,000
*GLENARTNEY	3,350
*GLENAMOY	3,350
*GLENADE	3,200
*GLENARIFFE	3,200
*GLENTARA	3,200
*GLENLUCE	3,200
*ABA	6,600
*GLENOGLE	6,000
*GLENAPP	6,000
*LA PAZ	3,200
*DORSETSHIRE	4,500
*SOMERSETSHIRE	4,500
BULLAREN	4,000
TISNAREN	4,000
BALBOA	3,100
BUENOS AIRES	3,100
ELMAREN	4,000
STUREHOLM	2,600
CANADA	3,100
FRITIOF	1,250
INDIEN	3,100
FRITZØE	640
WILLIAM PENN	4,500
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9089

IN TOTAL 191,290 I.HP. IN ACTUAL SERVICE.

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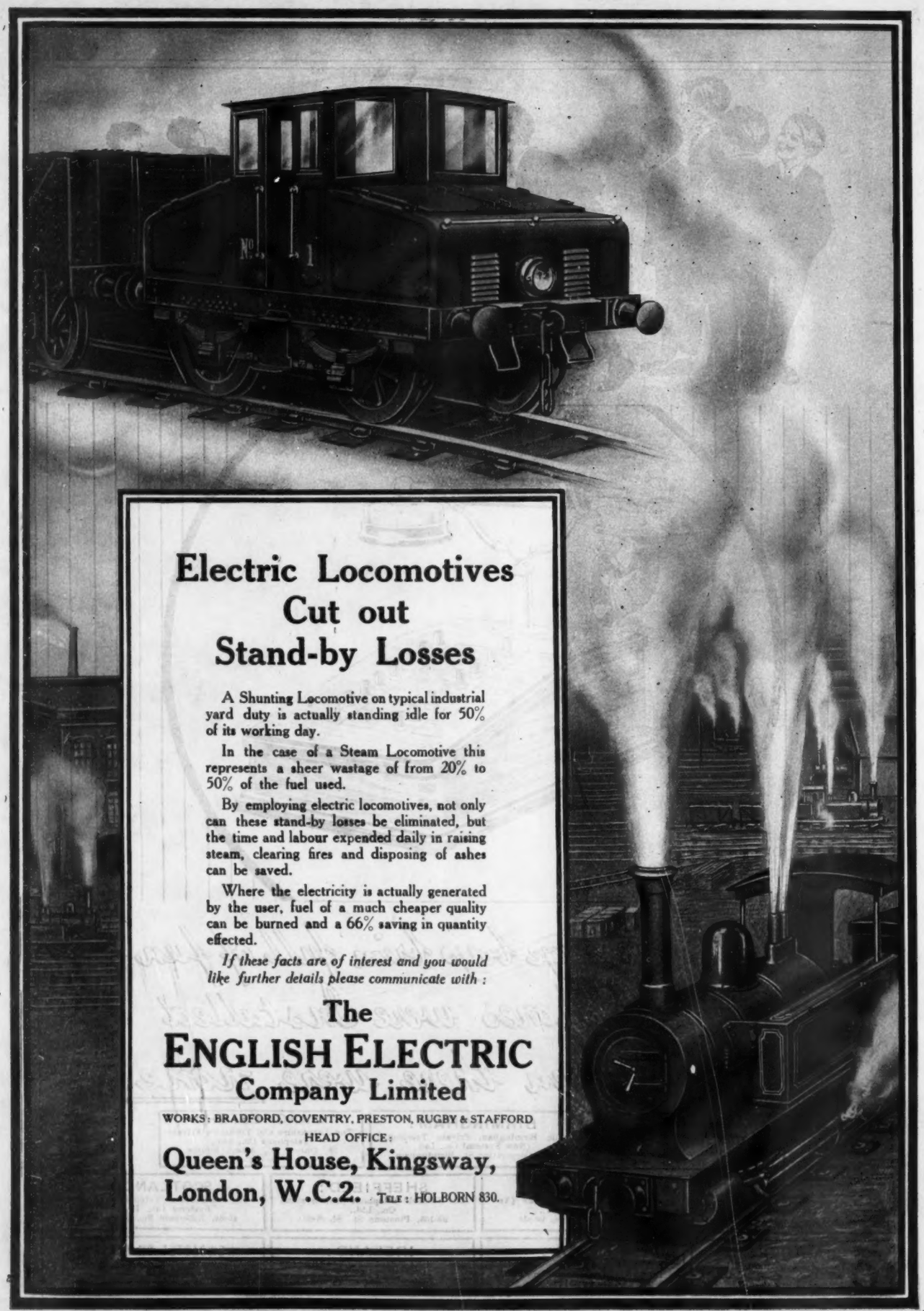
2288



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A Shunting Locomotive on typical industrial yard duty is actually standing idle for 50% of its working day.

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A RELIABLE OUTFIT AT MODERATE FIRST COST,
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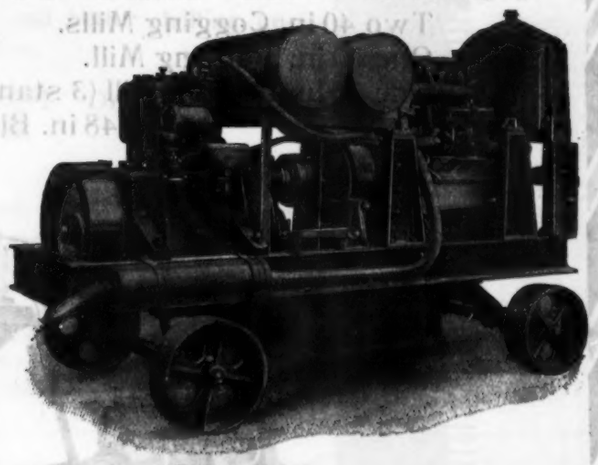

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THE ONLY RELIABLE THRUST BLOCK FOR HEAVY DUTIES

INDISPENSABLE FOR HEAVY WORM GEARS, PUMPS, TURBINES, &c.

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SPEED	460 *R.P.M.*
CO-EFFICIENT OF FRICTION	·0015

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WE SPECIALISE IN THE "MICHELL" AND HAVE GREATER EXPERIENCE IN MANUFACTURING THESE BEARINGS THAN ANY OTHER FIRM IN THE WORLD.

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have been installed by many of the most important Steel Works in this country and abroad — because they are specially designed with important new improvements to meet modern requirements.

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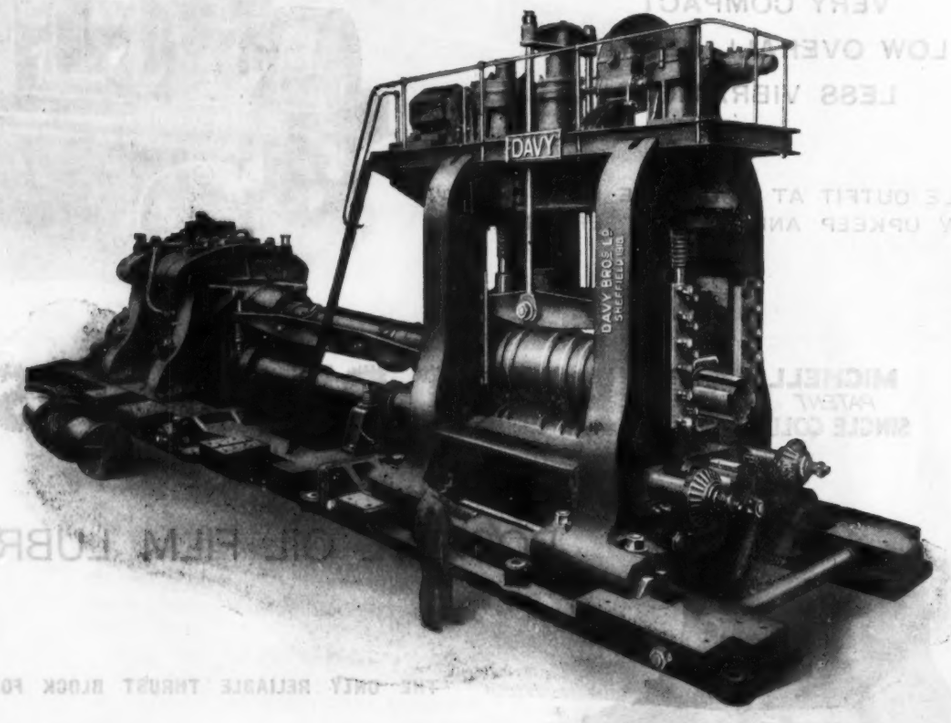

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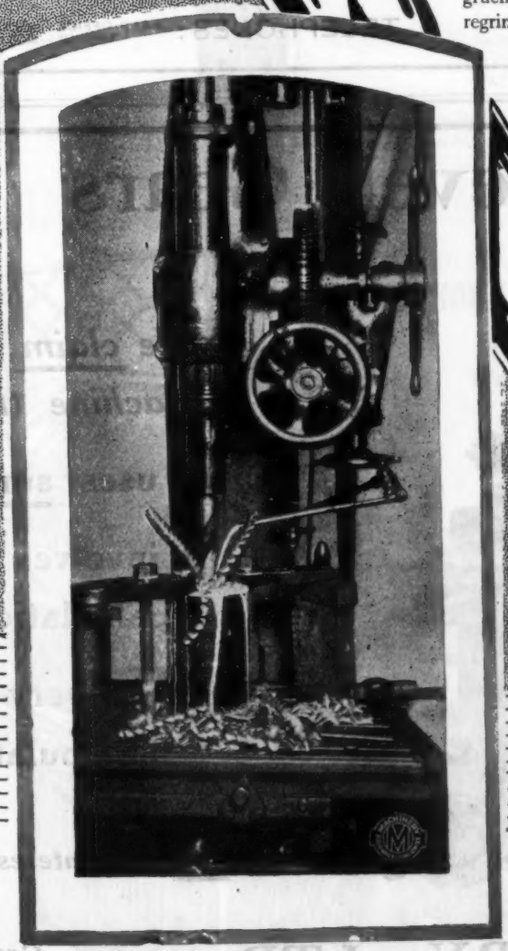
All standard sizes of SPEEDICUT Drills are held in stock for immediate delivery.



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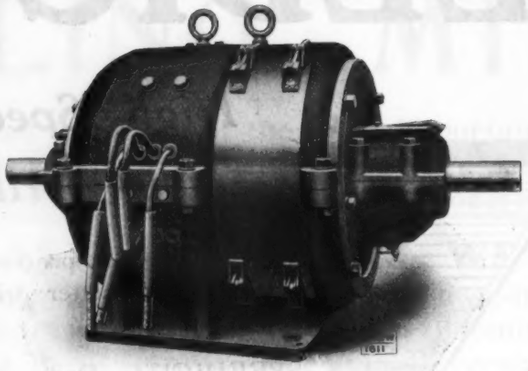
TOTALLY ENCLOSED dust-proof type of exceptionally robust construction.

Heavy overload capacity.



Top half of yoke removable without breaking any internal connection.

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9974

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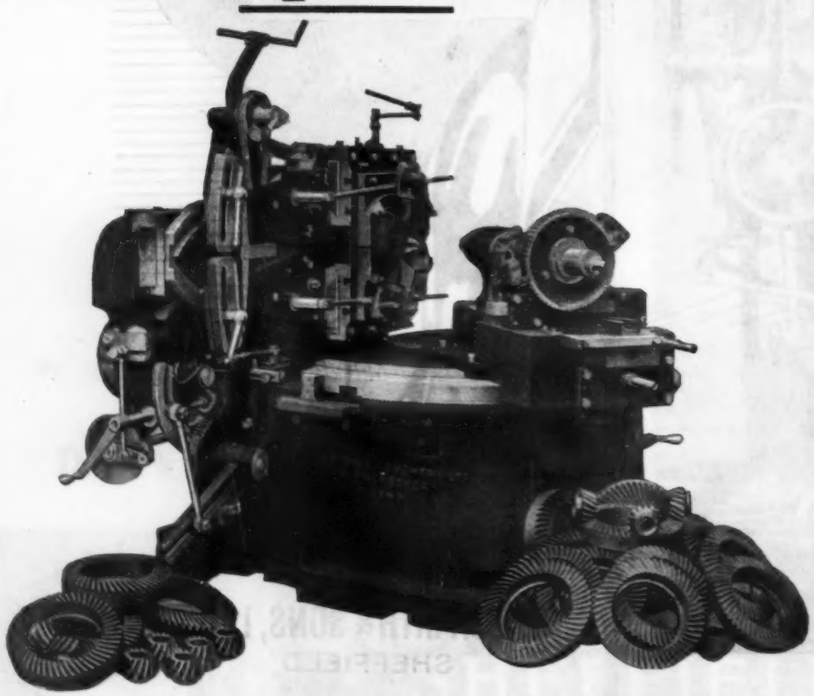

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Any tube easily removed and replaced in a few minutes without disturbing the brickwork or header.

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A Saving of

10% to 20% OF YOUR COAL BILL.

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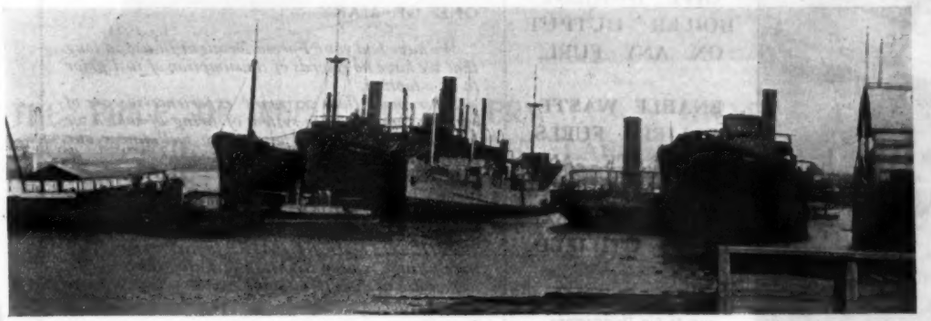

A recent photograph of vessels fitting out at our Shipbuilding Works.

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The following list of vessels launched or completed by us during the twelve months ending November, 1921, will be of interest to Shipowners.

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The largest Cargo Vessel built on the South Coast.

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The largest Oil-Tanker built on the South Coast. Propelled by geared turbines, with boilers installed to burn either coal or oil.

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(Patented).

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Typical 10,000 K.W. Surface Plant.

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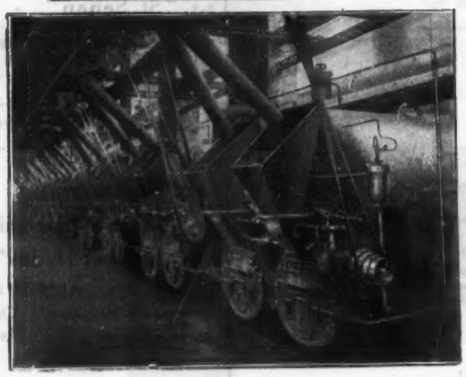
THE ONLY **NAME THAT EMBRACES** A FULL RANGE OF FUEL COMBUSTION SPECIALITIES *i.e.*:—

FORCED DRAUGHT FURNACES | **MECHANICAL STOKERS** | **REFUSE DESTRUCTOR FURNACES**



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ENABLE WASTE COLLIERY FUELS, i.e., SLACK AND DUST, ALSO COKE AND COKE BREEZE TO BE UTILIZED.

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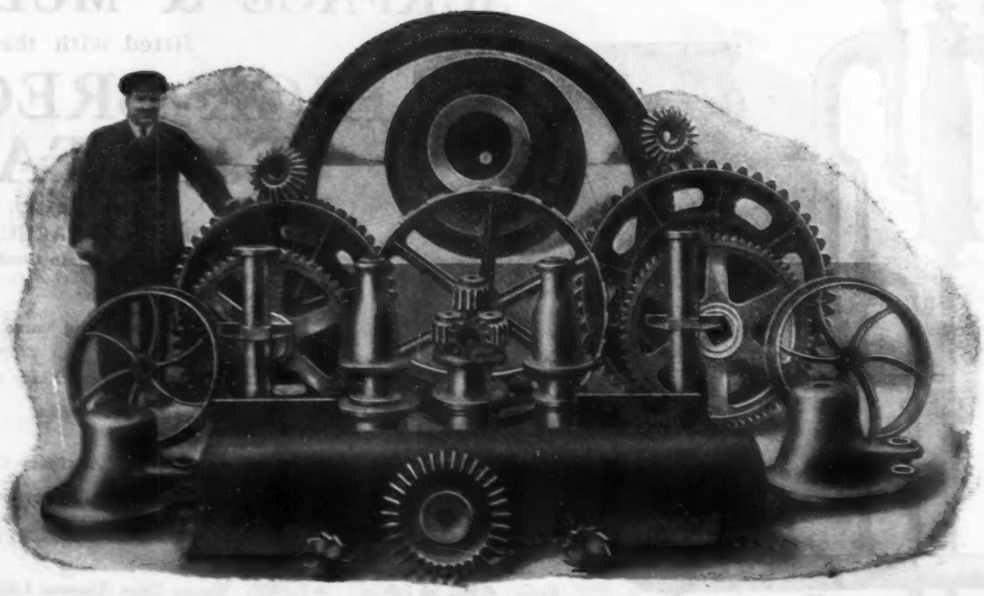

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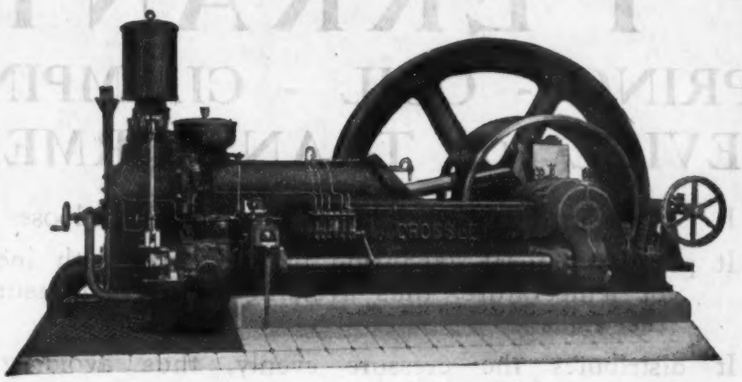

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OIL ENGINES

THE PRICE OF FUEL OIL IS VERY LOW. OWNERS AND MANAGERS OF FACTORIES AND POWER PLANTS CAN LARGELY REDUCE THEIR POWER COSTS.

For example: A plant of 50 B.HP. consisting of a steam engine with oil fired boiler would require about 80 lb. of fuel oil per hour, whereas a Crossley Cold-Starting Oil Engine would use only 20 to 25 lb. of fuel oil per hour, which at the present price of oil would result in a SAVING OF £4 to £5 PER WEEK IN FUEL COST ALONE and at the same time save a considerable amount in cost of water, rateable value and rent of space occupied.

May we advise you on how to reduce your power costs? 9439

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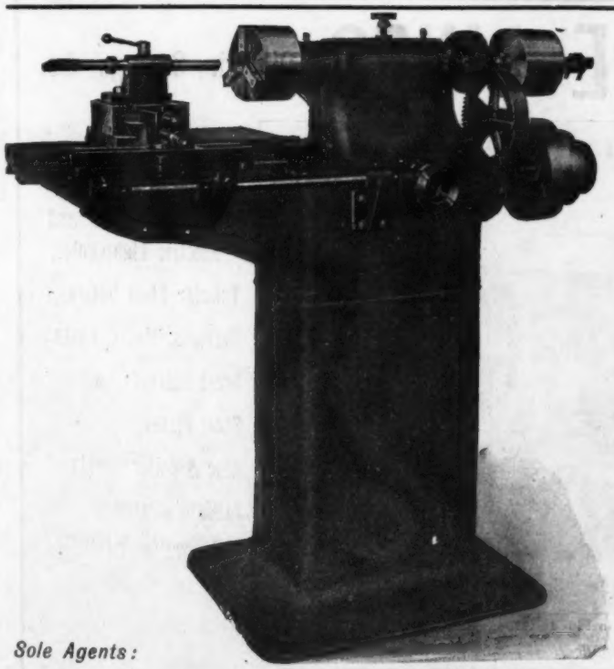

Fischer Automatic Oil Grooving Machine.

Capacity 10 in. over the carriage and a stroke of 0 to 8 in. Will cut straight or spiral grooves and will handle from five to ten times the amount of work that is possible by any other method.

Illustration shows machine equipped with Relieving Attachment and Air Operated Chuck.

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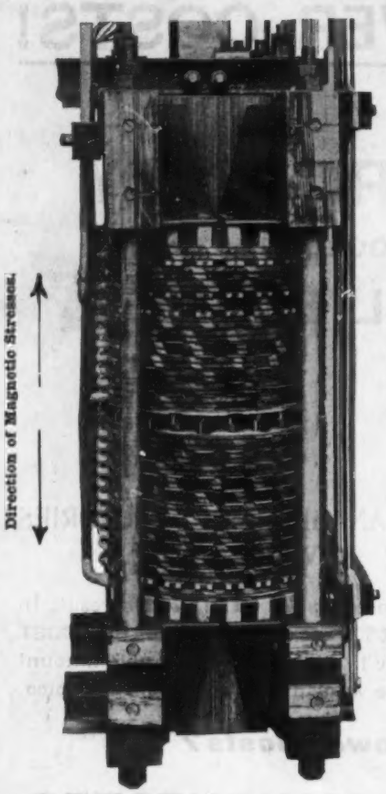
"THE RIGHT THING IN THE RIGHT PLACE."



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SPRING - COIL - CLAMPING DEVICE FOR TRANSFORMERS

1. It "takes up" coil shrinkage, thus avoiding loose coils.
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4. It is placed midway between the ends of the winding where the magnetic stresses being balanced do not tend to compress the springs, thus avoiding undesired movement of the coils.

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Light Lapwelded Steel Pipes.
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Loose Flange Joint Tubes.
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The Fans work equally well as exhausters, being capable of setting up high suction water gauges.

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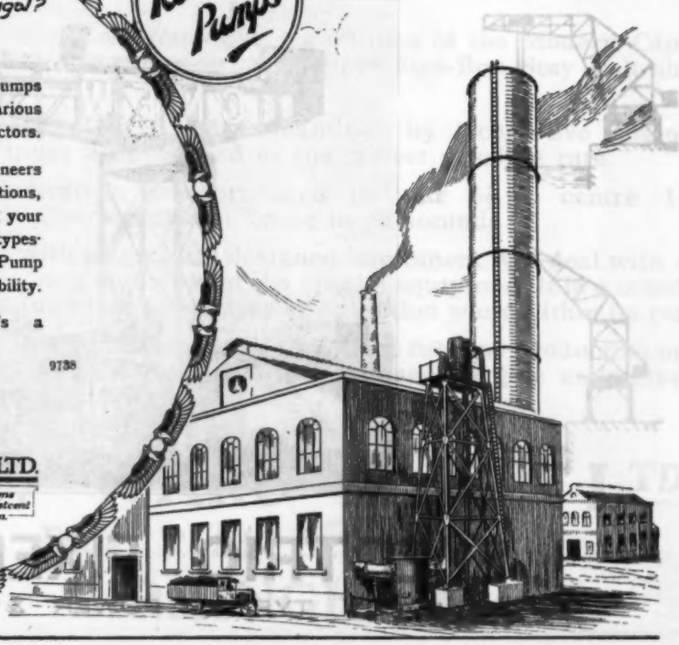

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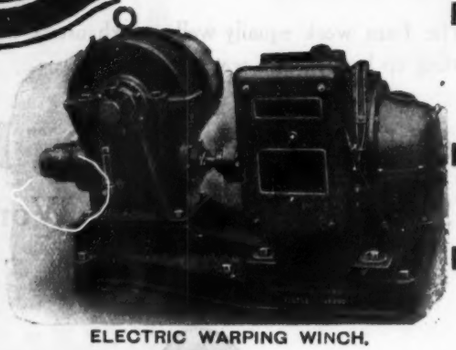

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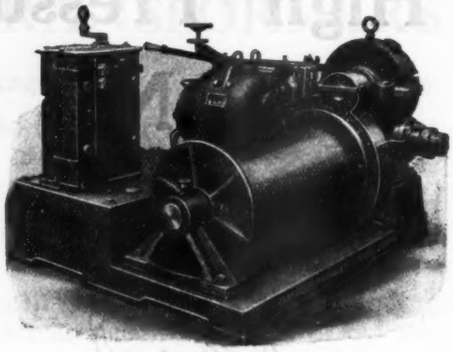

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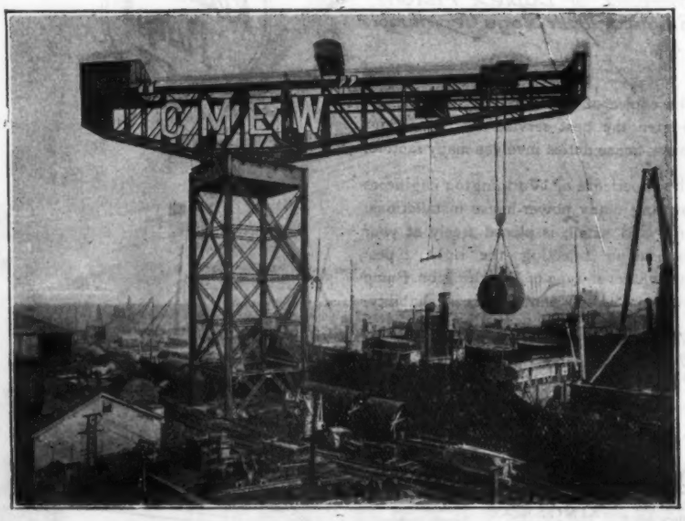

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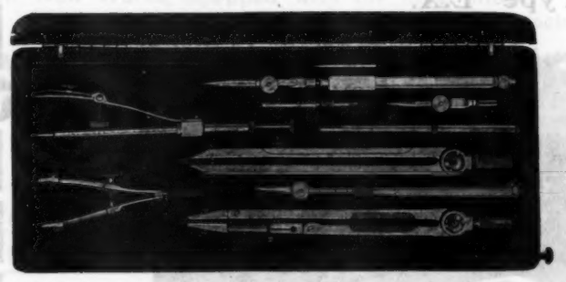

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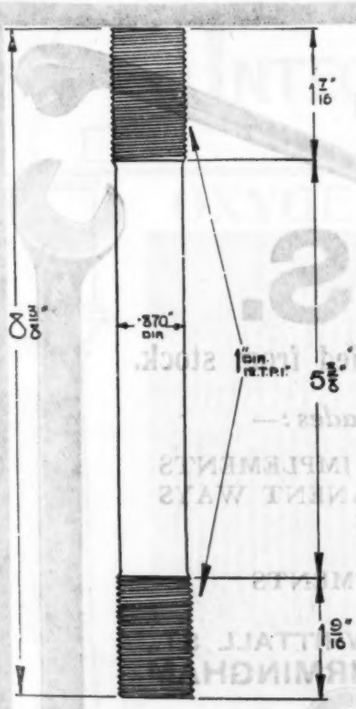

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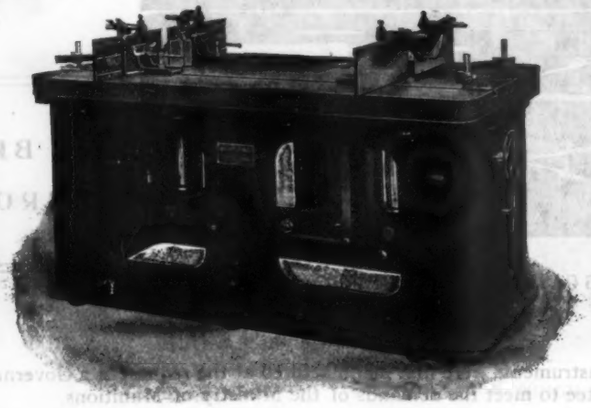

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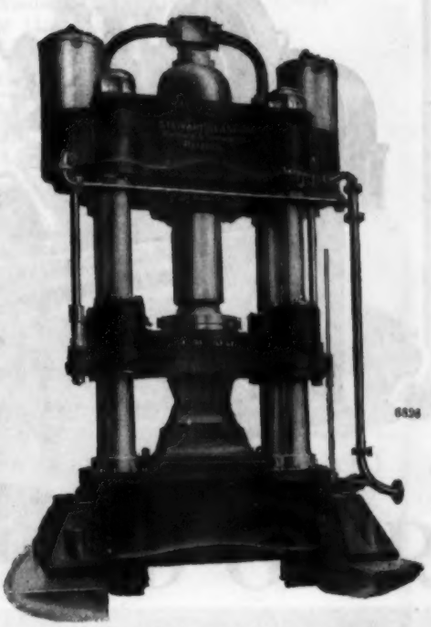

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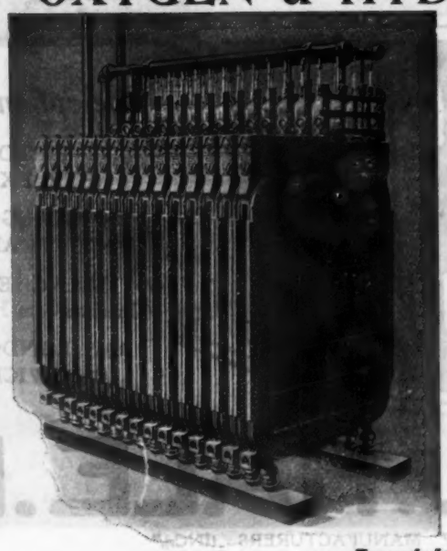

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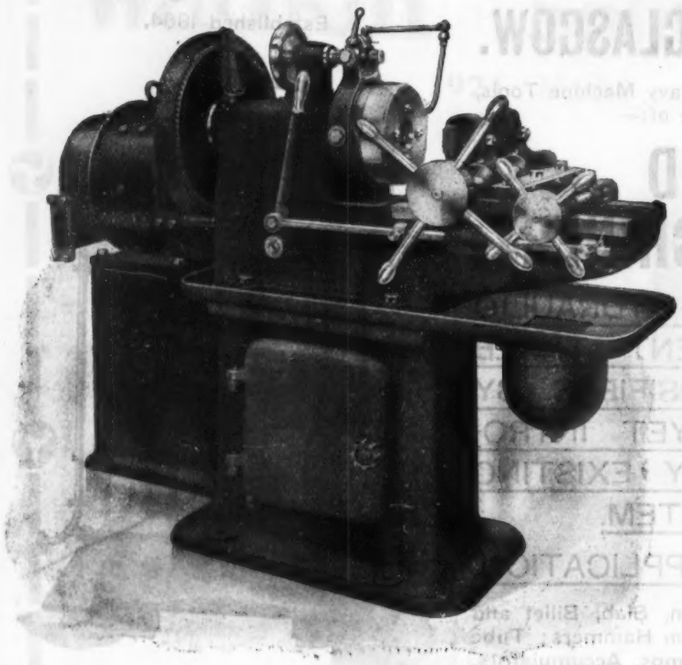

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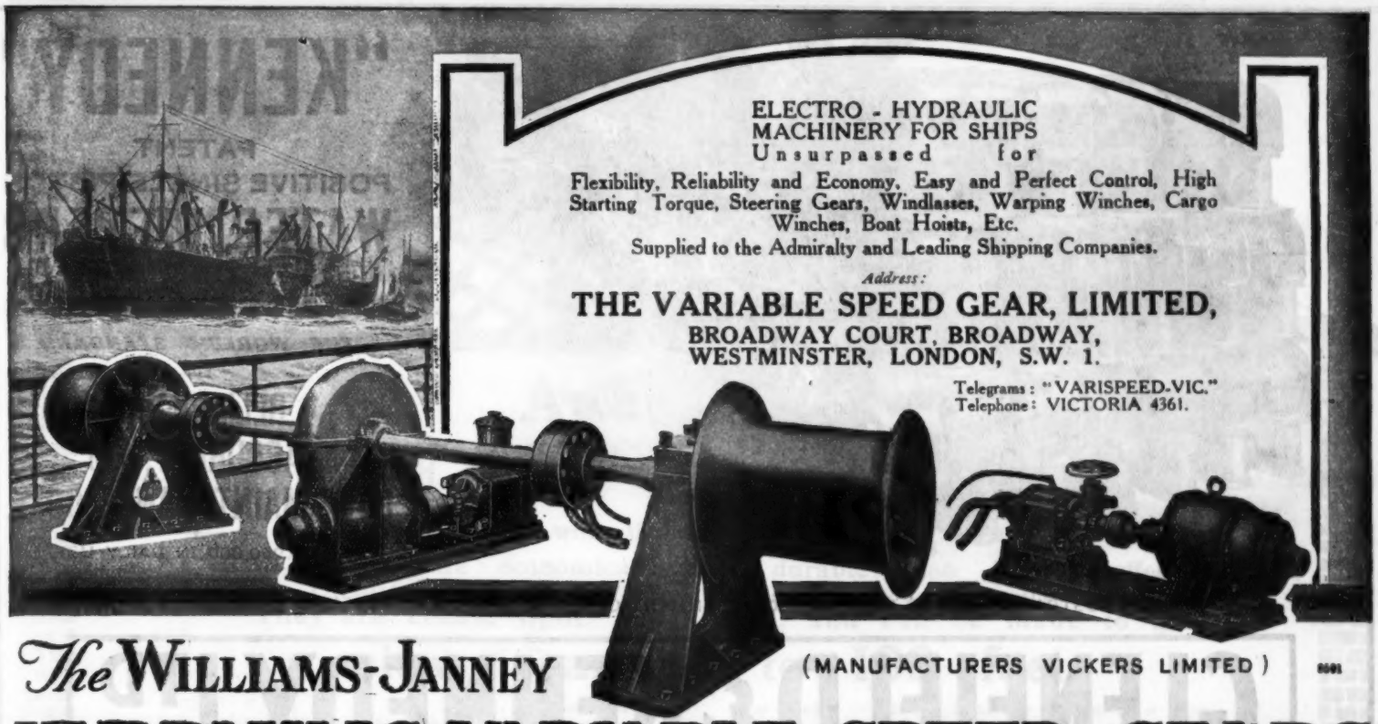

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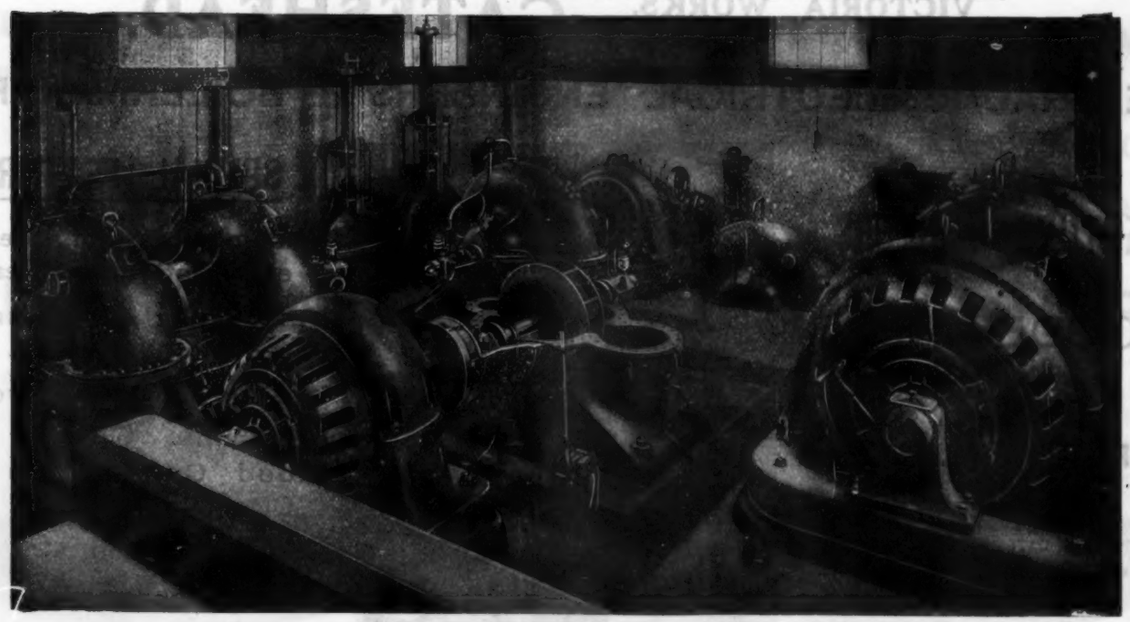

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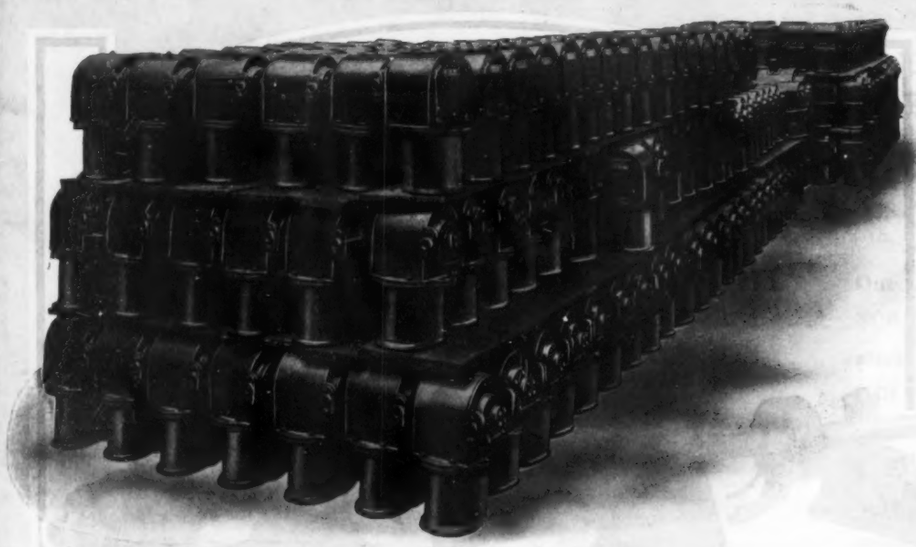

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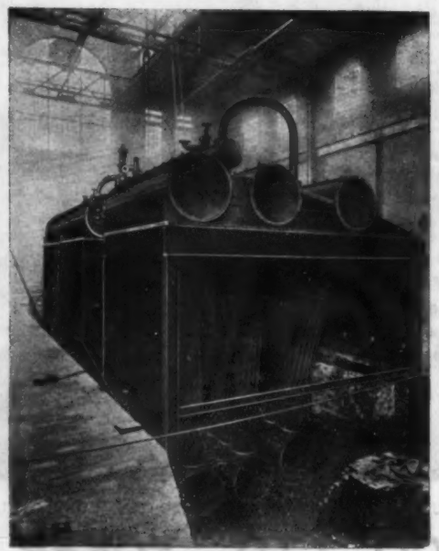

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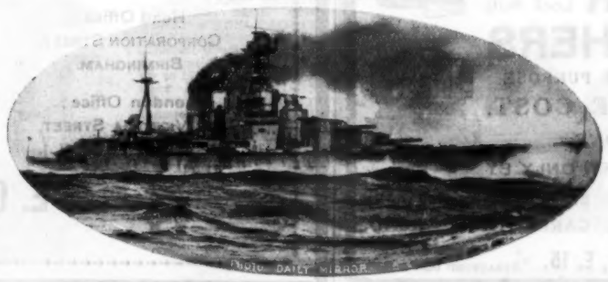

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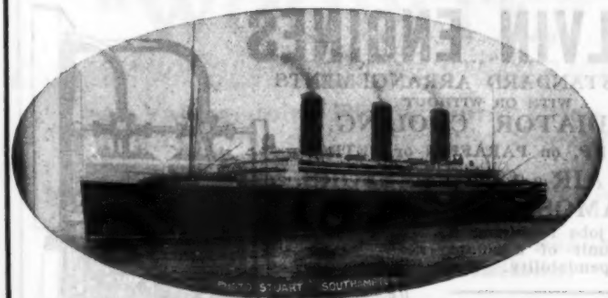

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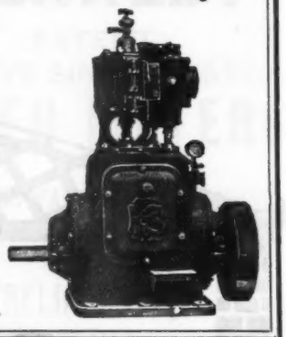

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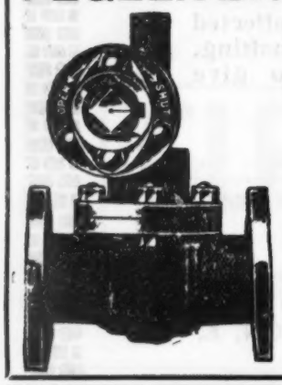

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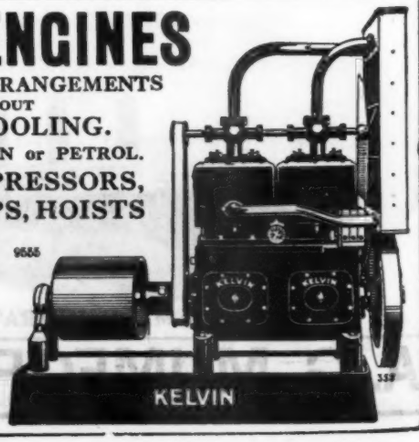

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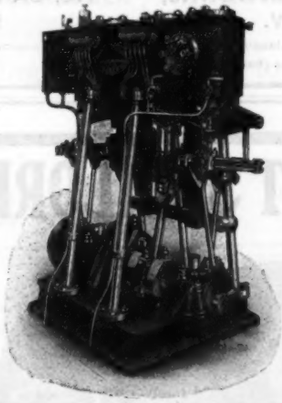

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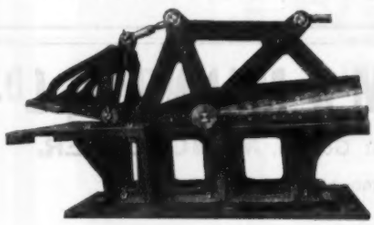

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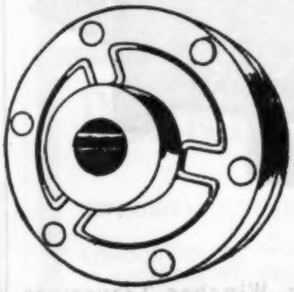

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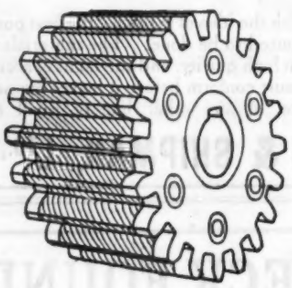

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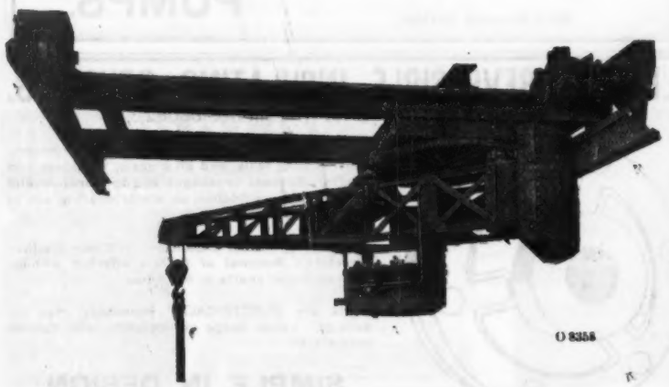

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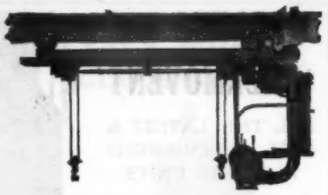

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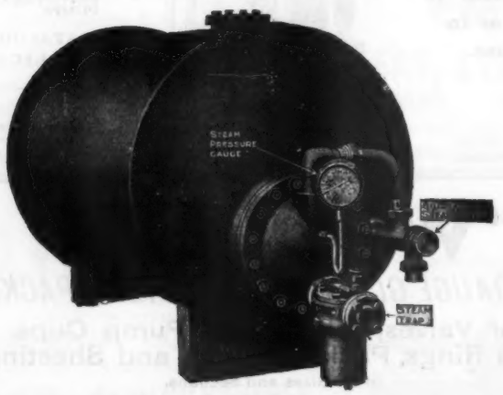

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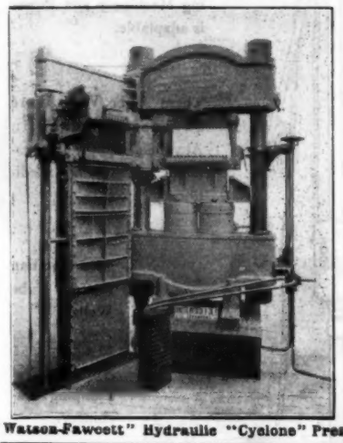

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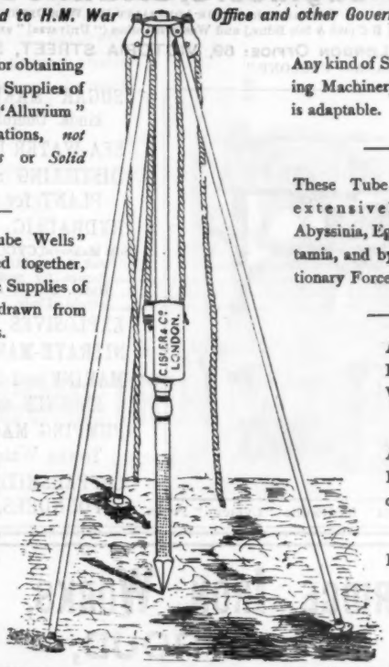

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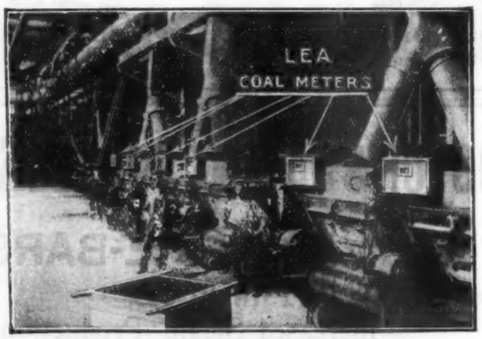

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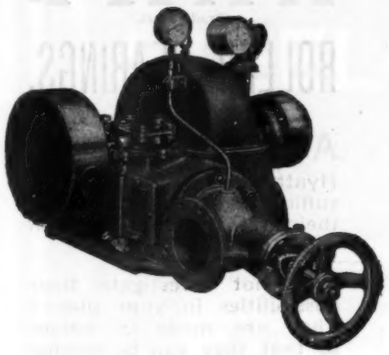

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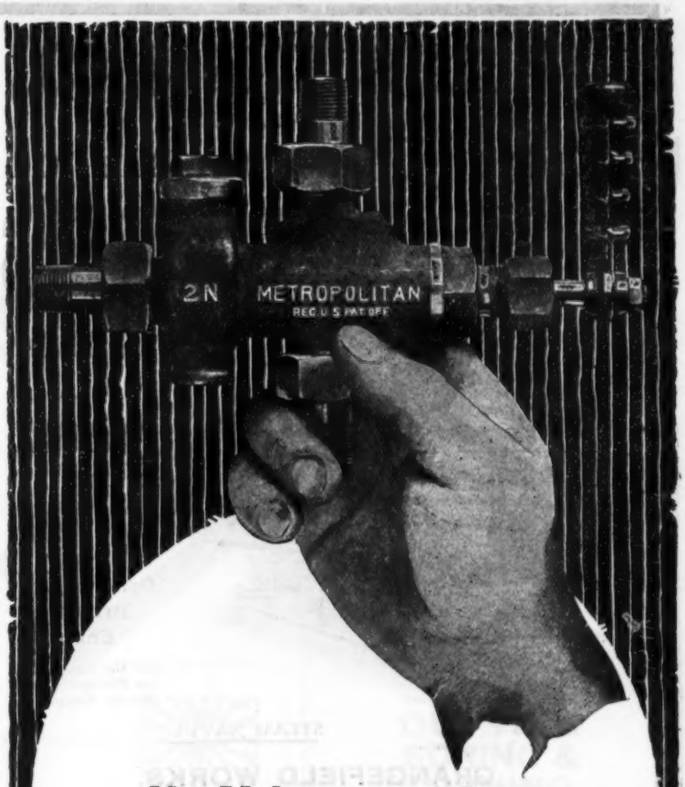

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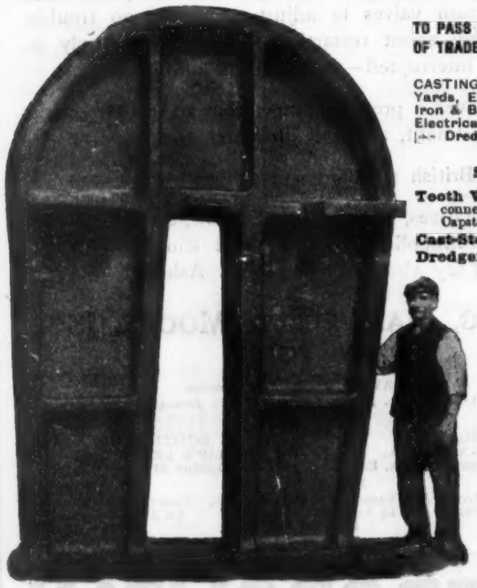

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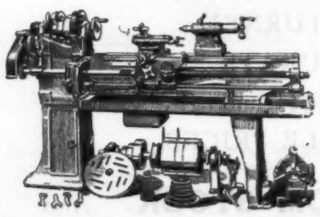

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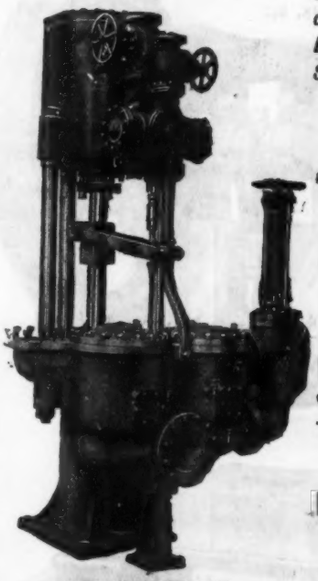

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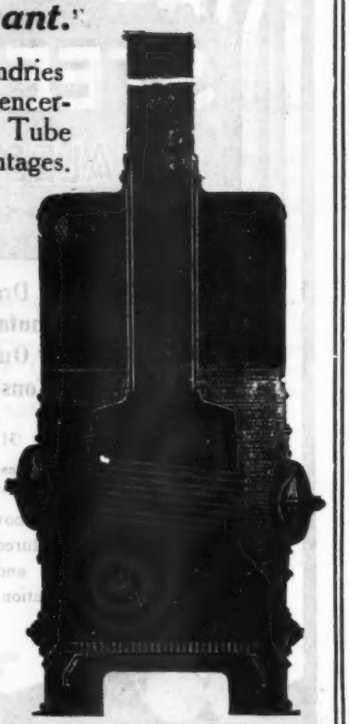

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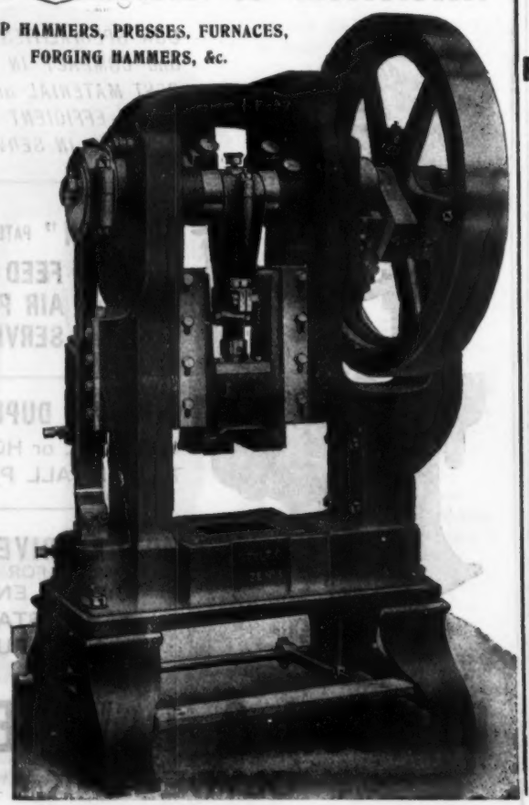

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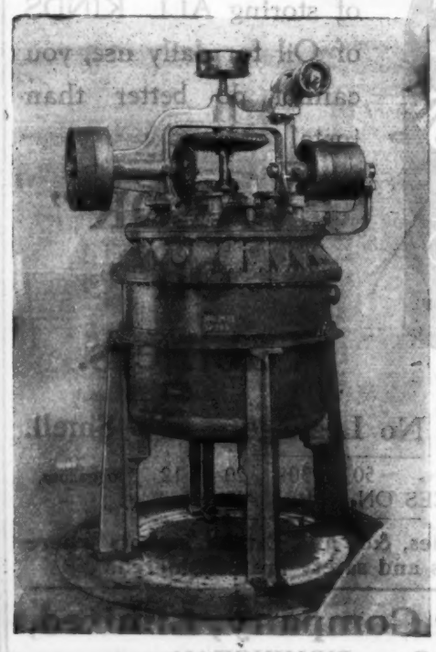

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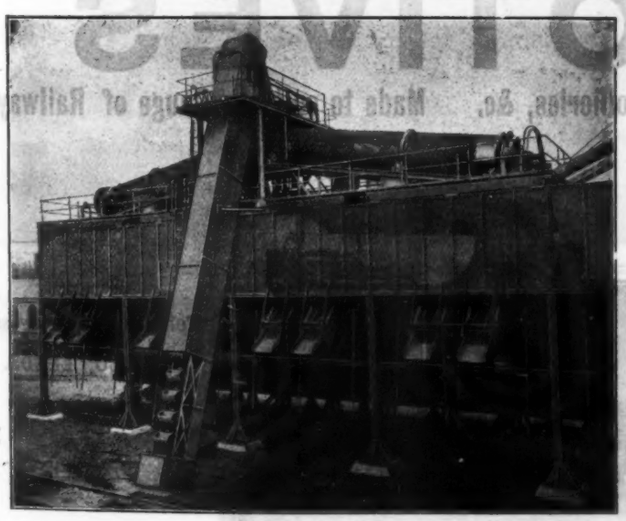

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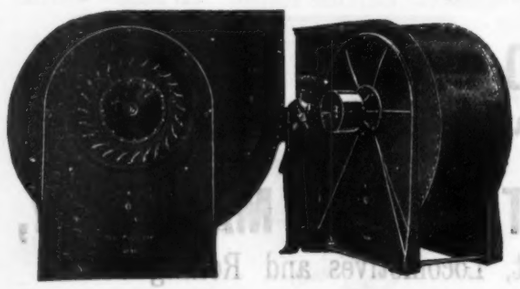

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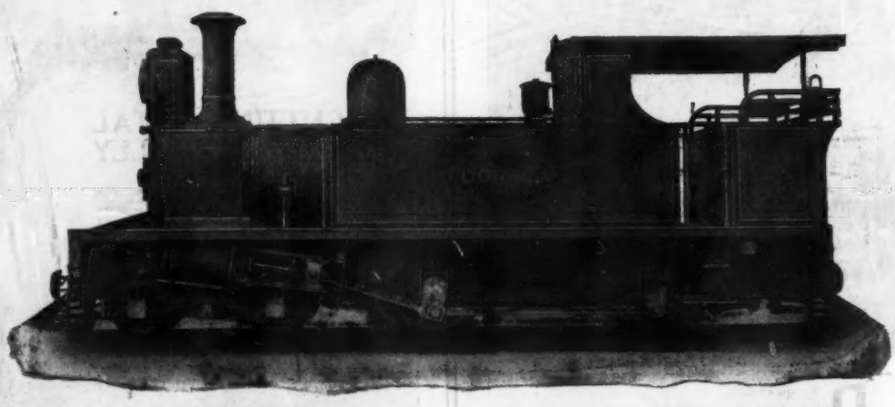

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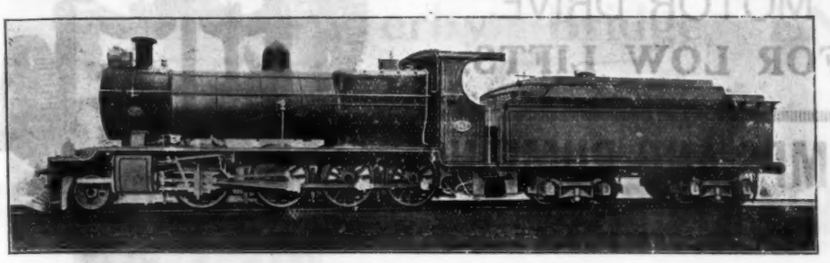

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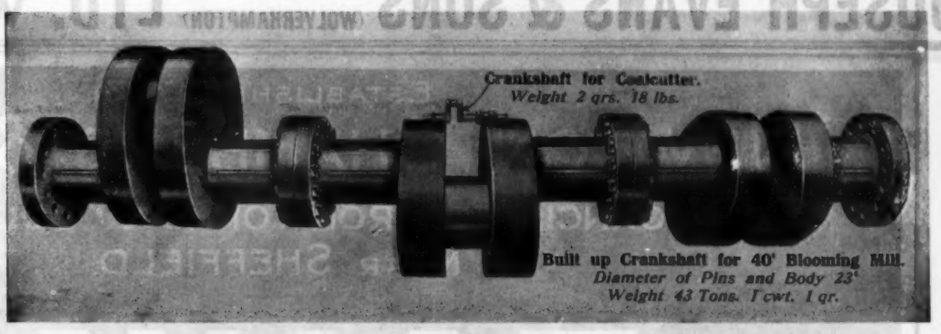

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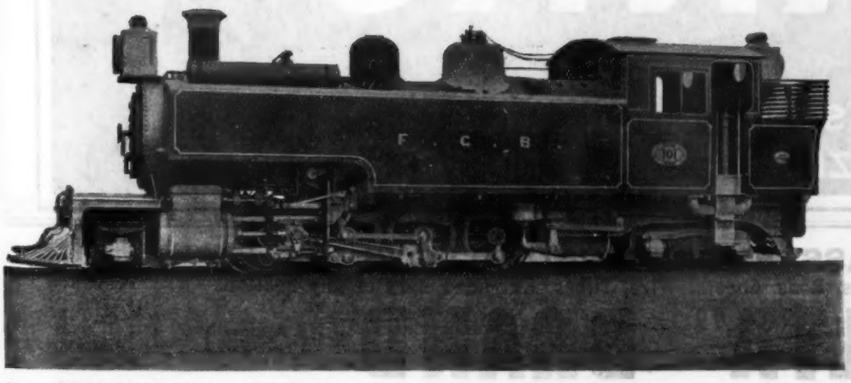

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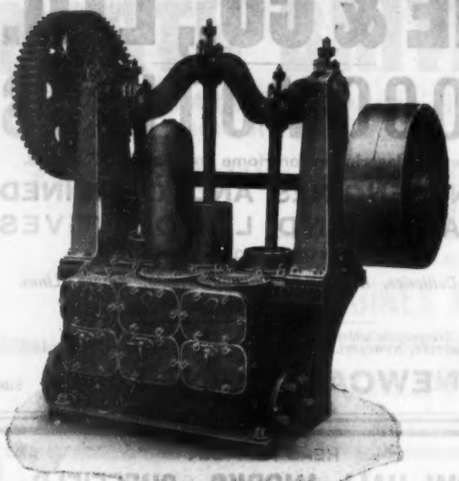

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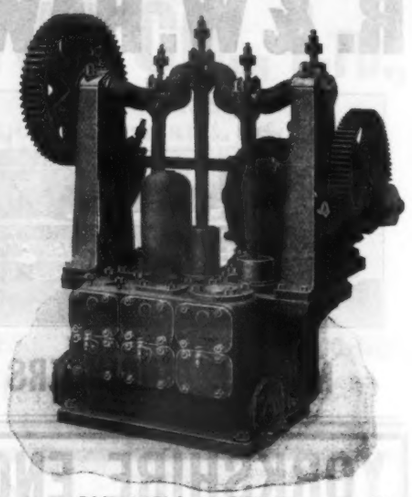

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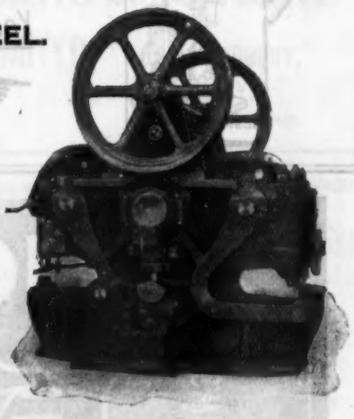

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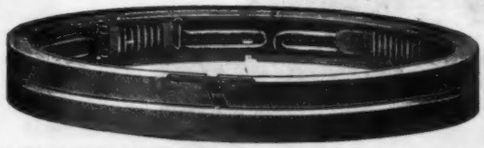

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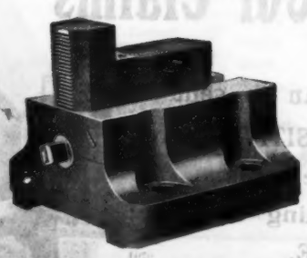

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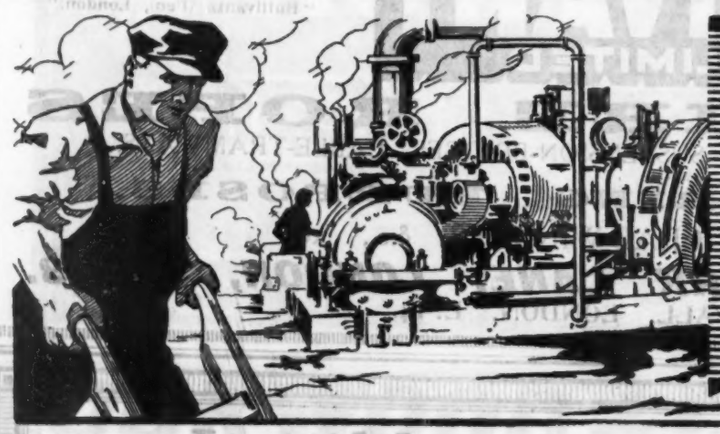

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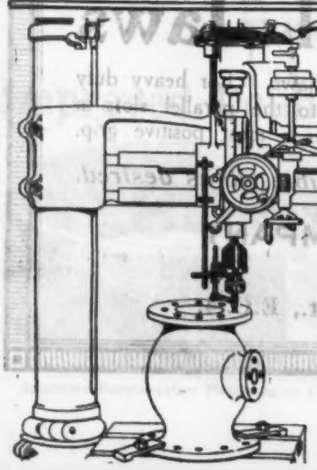

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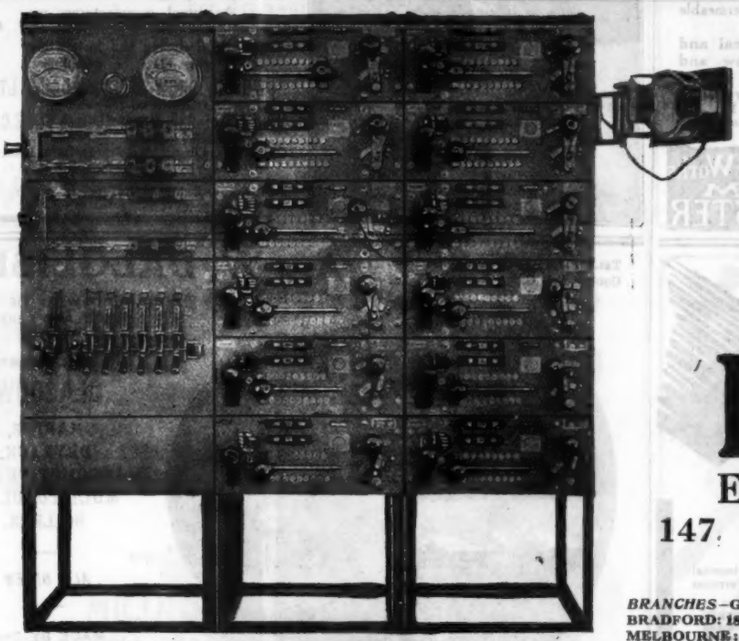

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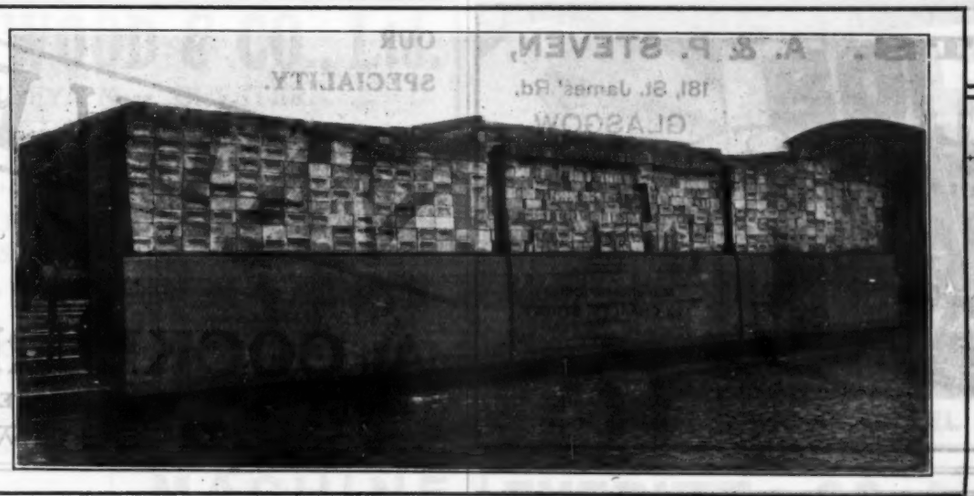

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(c) The "R.P." covering removed for purpose of photographing, Sept. 26th, 1921. Sixteen years afterwards the original bright surface is unmarked.

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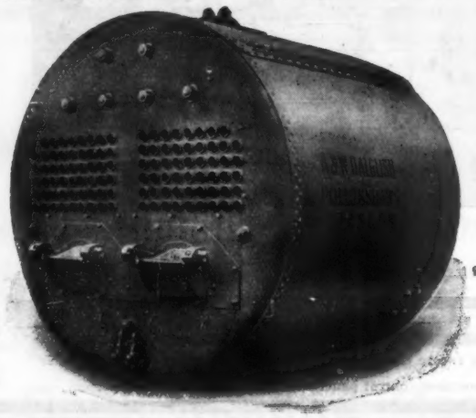

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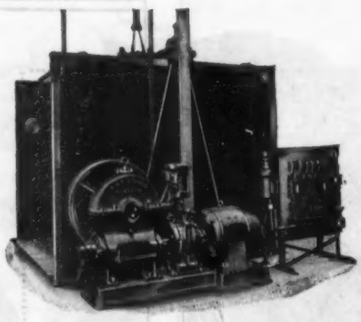

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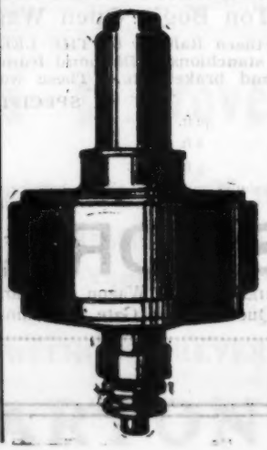

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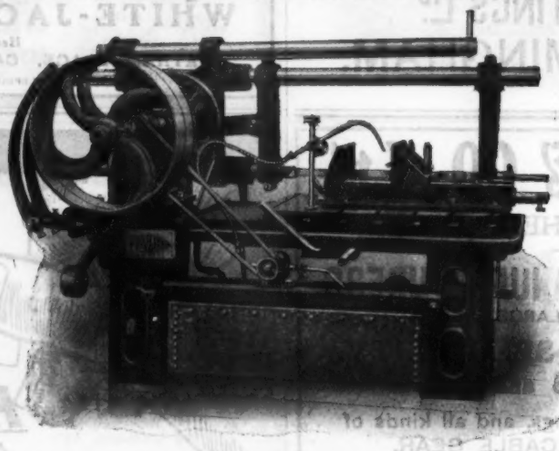

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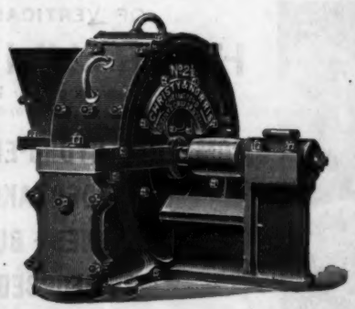

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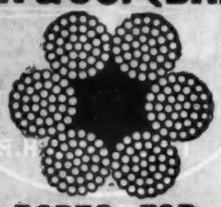

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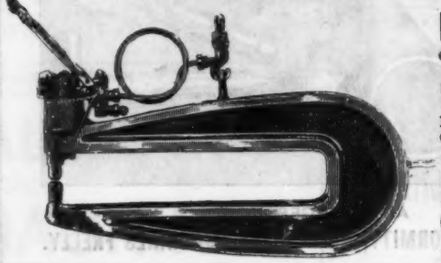

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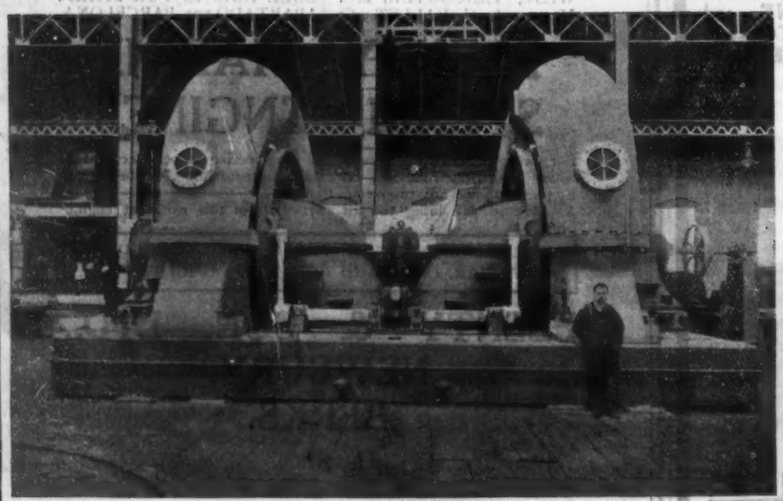

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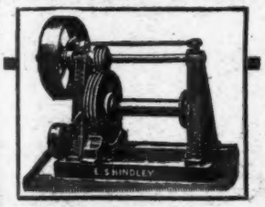
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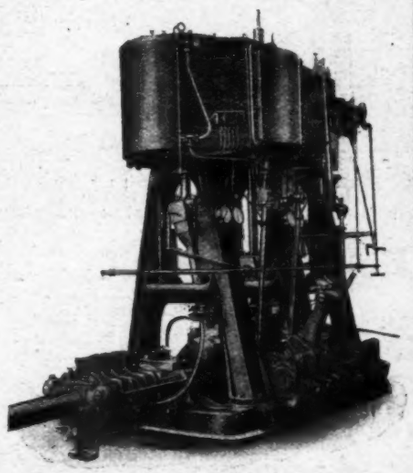
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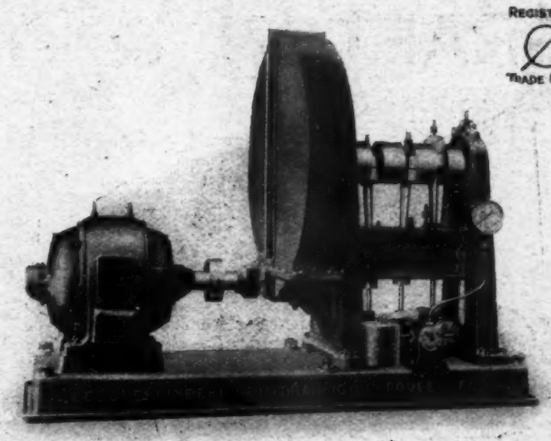
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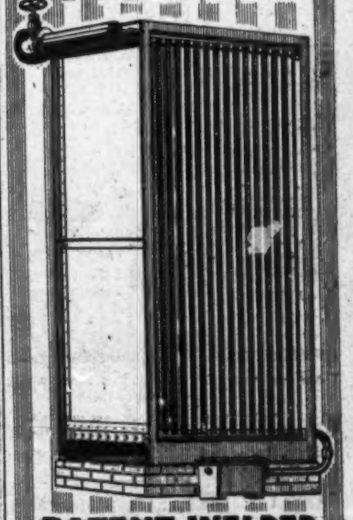
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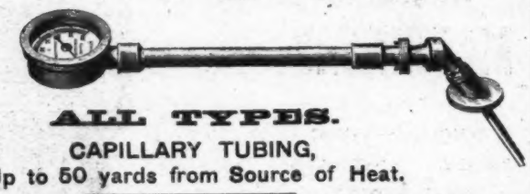
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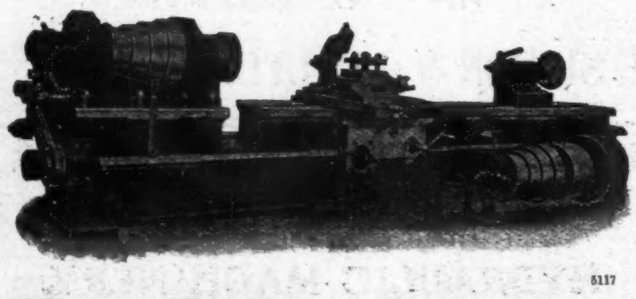
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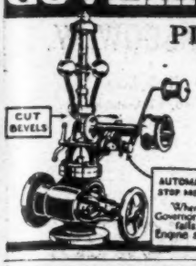

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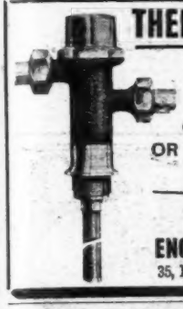

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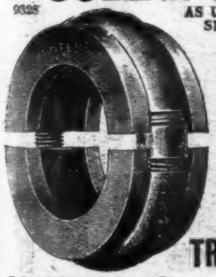

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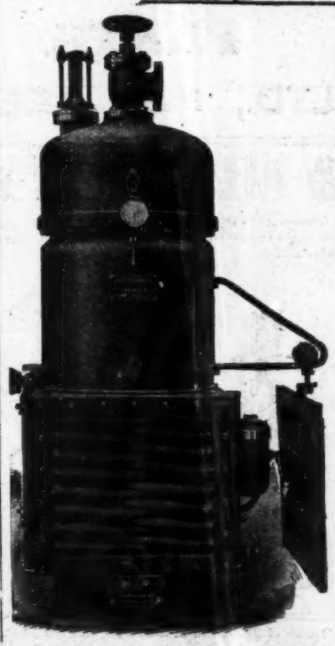

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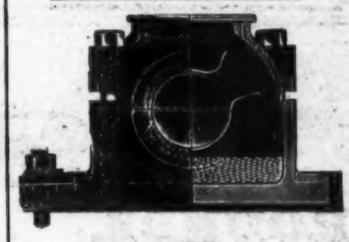

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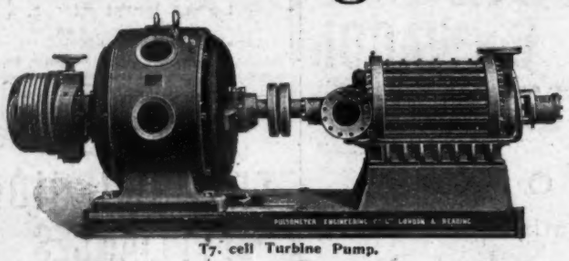

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